Aasen, G. (2009). Fish Salvage at the State Water Project's and Central Valley Project's Fish Facilities during 2008. IEP Newsletter. 22: 8.

Aasen, G. (2010). Fish Salvage at the State Water Project's and Central Valley Project's Fish Facilities during 2009. IEP Newsletter. 23: 8.

Aasen, G. A. (1999). "Juvenile delta smelt use of shallow-water and channel habitats in California's Sacramento-San Joaquin Estuary." California Fish and Game 85(4): 161-169.

Juvenile delta smelt, Hypomesus transpacificus, densities were significantly greater in shallow water in Honker Bay and Sherman Lake than in adjacent channels in 1993, indicating that they used shallow areas in bay and flooded island environments as nursery habitats. Densities and lengths were significantly greater on high than low tides in shallow water in Honker Bay, but not in the adjacent channel, suggesting that delta smelt moved tidally between Honker and Grizzly bays. Delta smelt densities did not differ between shallow water and channels in the riverine environments of Montezuma Slough, the lower San Joaquin River, and Cache Slough, presumably because shallow areas were smaller and no embayments existed to retain delta smelt. Delta smelt may be larger in shallow water in Honker Bay and Sherman Lake because 1) fish in shallow water were older and consequently larger or 2) residence time was longer and foraging success was better, resulting in increased growth rates. Availability of shallow habitats to delta smelt increases in high-outflow years when hydrodynamic transport locates the delta smelt population downstream in Suisun, Grizzly, and Honker bays.

Aasen, G. A., D. A. Sweetnam, et al. (1998). "Establishment of the wakasagi, Hypomesus nipponensis, in the Sacramento-San Joaquin Estuary." California Fish and Game 84(1): 31-35.

Recent evidence indicates that the exotic wakasagi, Hypomesus nipponensis, is now resident in the Sacramento-San Joaquin Estuary, making it sympatric with the state and federally listed threatened delta smelt, Hypomesus transpacificus. Interactions between these similar species may affect delta smelt recovery.

Abbott, R. R. and R. Obernolte (2010). Habitat restoration in the San Francisco Estuary to increase salmonid smolt foraging opportunities. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Salmonid smolts migrating through the San Francisco Estuary have limited foraging opportunities as indicated by a reduction in their Condition Factor (CF), reduced body lipid content and where nearly half have empty stomachs as they leave the Golden Gate. Extensive mud flats provide limited foraging opportunities for salmonid smolts. The loss of habitat complexity and vertical structures in the Estuary has reduced the potential for a robust community of organisms that could provide more salmonid smolt foraging opportunities. Two large artificial reefs have been constructed in central San Francisco Bay specifically to provide foraging habitat for migratory salmonid smolts. Data collected on the community of organisms found in the reef systems compared to control areas and acoustic fish tracking demonstrate the increase in foraging opportunities and the extended utilization of the reefs by late fall-run Chinook, steelhead and green sturgeon. A conceptual model of the reef system function in the San Francisco Estuary provides a tool for management consideration of methods to increase salmonid survival through the Estuary and improve physiological readiness for ocean phase survival.

Abib-Samii, J. (2010). 2010 Spring Kodiak Trawl Survey. IEP Newsletter. 33: 5.

Abu-Saba, K. E. and A. R. Flegal (1995). "Chromium in San Francisco Bay: Superposition of geochemical processes causes complex spatial distributions of redox species." Marine Chemistry 49(2-3): 189-199.

Processes controlling the geochemical cycle of Cr in San Francisco Bay were characterized with analyses of water samples taken from 25 stations distributed throughout the estuary. Mixing of water masses, localized inputs, in-situ reduction, and sediment resuspension contributed to complex spatial distributions of dissolved (< 0.45 mu m) Cr(III) and Cr(VI), as well as suspended particulate Cr. Total

dissolved Cr concentrations in the bay ranged from 1.9 to 8.3 nM, with the maximum concentration observed at the head of the estuary (the Delta) that was attributed to a relatively large input (5.2 nM) of Cr(III) within the San Joaquin River. The calculated Cr(III) scavenging residence time in that region was relatively long (> 3 days) for a particle reactive trace metal, suggesting either localized inputs or complexation by colloidal/organic matter. There was also a relative excess (2.6 nM) of Cr(VI) in another section of the Delta. Mass balance calculations showed that excess was the same order of magnitude as reported point source loadings of Cr in that area. The subsequent depletion of Cr(VI), along with a concurrent increase in Cr(III) concentration in a shallow region of the Delta, was tentatively attributed to in-situ reduction.

Ackerman, J. T. and C. Eagles-Smith (2010). Mercury bioaccumulation and toxicity to birds in San Francisco Bay Estuary. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Mercury contamination in waterbirds is a significant concern in the San Francisco Bay-Delta because the Estuary has a legacy of mercury contamination from mercury and gold mining and waterbirds rely heavily on wetland habitats that are known to produce methyl mercury, the most toxic and bioavailable form of mercury. We examined mercury bioaccumulation and effects on avian reproductive success in waterbirds that breed within the Estuary and found impaired reproduction in several species and lifestages. Upon arrival within the Estuary, birds rapidly accumulated mercury prior to and during the breeding season. We found sublethal effects of mercury on adult birds, including demethylation of mercury in bird livers. Methylmercury in adults was then transferred proportionately to offspring, potentially impairing reproduction. In fish-eating Forster’s Terns, we found that: 1) failed-to-hatch eggs and abandoned eggs had higher mercury concentrations than randomly sampled eggs, 2) the prevalence of embryo malpositions increased with egg mercury concentrations, 3) hatching success of eggs decreased with mercury concentrations, and 4) nest survival decreased with mercury concentrations. In invertebrate-eating Black-necked Stilts, we found that dead chicks had higher mercury concentrations than live, randomly sampled chicks of similar age. Altogether, these results suggest that mercury contamination may currently be impairing bird reproduction and, perhaps, population growth within the Estuary. In order to ensure that restoration efforts of the South Bay Salt Pond Restoration Project are successful, it will be valuable to establish a long-term, annual monitoring program for waterbird mercury concentrations and reproductive success.

Ackerman, J. T., C. A. Eagles-Smith, et al. (2008). "Mercury Concentrations in Blood and Feathers of Prebreeding Forster's Terns in Relation to Space Use of San Francisco Bay, California, USA, Habitats." Environmental Toxicology and Chemistry 27(4): 897-908.

We examined mercury concentrations and space use of prebreeding Forster's terns (Sterna forsteri) in San Francisco Bay, California, USA, to assess factors influencing mercury levels in piscivorous birds. In 2005 and 2006, we collected blood and feathers from 122 Forster's terns and radio-marked and tracked 72 terns to determine locations of dietary mercury uptake. Capture site and capture date were the most important factors explaining variation in blood mercury concentrations (geometric mean +/- standard error: 1.09 +/- 0.89 mu g/g wet wt), followed by sex and year. Accordingly, radiotelemetry data revealed that Forster's terns generally remained near their site of capture and foraged in nearby salt ponds, managed and tidal marshes, and tidal flats. In contrast, capture site and capture date were not important factors explaining variation in feather mercury concentrations, probably because feathers were grown on their wintering grounds several months prior to our sampling. Instead, sex and year were the most important factors explaining mercury concentrations in breast feathers (9.57 +/- 8.23 mu g/g fresh wt), and sex was the most important factor for head feathers (6.94 +/- 7.04 mu g/g fresh wt). Overall, 13 and 22% of prebreeding Forster's terns were estimated to be at high risk for deleterious effects due to mercury concentrations in blood (>3.0 mu g/g wet wt) and feathers (>20.0 mu g/g fresh wt), respectively. Breeding terns are likely to be even more at risk because blood mercury concentrations more than tripled during the 45-d prebreeding time period. These data illustrate the importance of space use and tissue type in interpreting mercury concentrations in birds.

Ackerman, J. T., C. A. Eagles-Smith, et al. (2007). "Mercury concentrations and space use of pre-breeding American avocets and black-necked stilts in San Francisco Bay." Science of the Total Environment 384(1-3): 452-466.

We examined factors influencing mercury concentrations in pre-breeding American avocets (Recurvirostra americana) and black-necked stilts (Himantopus mexicanus), the two most abundant breeding shorebirds in San Francisco Bay, California. We tested the effects of species, site, sex, year, and date on total mercury concentrations in blood of pre-breeding adult birds and used radio telemetry to determine space use and sites of dietary mercury exposure. We collected blood from 373 avocets and 157 stilts from February to April in 2005 and 2006, radio-marked and tracked 115 avocets and 94 stilts, and obtained 2393 avocet and 1928 stilt telemetry locations. Capture site was the most important factor influencing mercury concentrations in birds, followed by species and sex. Mercury concentrations were higher in stilts (geometric mean: 1.09 mu g g super(-) super(1) wet weight [ww]) than in avocets (0.25 mu g g super(-) super(1) ww) and males (stilts: 1.32 mu g g super(-) super(1) ww; avocets: 0.32 mu g g super(-) super(1) ww) had higher levels than females (stilts: 1.15 mu g g super(-) super(1) ww; avocets: 0.21 mu g g super(-) super(1) ww). Mercury concentrations were highest for both species at the southern end of San Francisco Bay, especially in salt pond A8 (stilts: 3.31 mu g g super(-) super(1) ww; avocets: 0.58 mu g g super(-) super(1) ww). Radio telemetry data showed that birds had strong fidelity to their capture site. Avocets primarily used salt ponds, tidal marshes, tidal flats, and managed marshes, whereas stilts mainly used salt ponds, managed marshes, and tidal marshes. Our results suggest that variation in blood mercury concentrations among sites was attributed to differences in foraging areas, and species differences in habitat use and foraging strategies may increase mercury exposure in stilts more than avocets.

Ackerman, J. T., J. Y. Takekawa, et al. (2008). "Mercury contamination and effects on survival of American avocet and black-necked stilt chicks in San Francisco Bay." Ecotoxicology 17(2): 103-116.

We evaluated whether mercury influenced survival of free-ranging American avocet (Recurvirostra americana) and black-necked stilt (Himantopus mexicanus) chicks in San Francisco Bay, California. Using radio telemetry, we radio-marked 158 avocet and 79 stilt chicks at hatching and tracked them daily until their fate was determined. We did not find strong support for an influence of in ovo mercury exposure on chick survival, despite observing a wide range of mercury concentrations in chick down feathers at hatching (0.40-44.31 mu g g super(-1) fw). We estimated that chick survival rates were reduced by less than or equal to 3% over the range of observed mercury concentrations during the 28-day period from hatching to fledging. We also salvaged newly-hatched chicks that were found dead during routine nest monitoring. In contrast to the telemetry results, we found that mercury concentrations in down feathers of dead chicks were higher than those in randomly-sampled live chicks of similar age. However, capture site was the most important variable influencing mercury concentrations, followed by year, species, and hatching date. Although laboratory studies have demonstrated negative effects of environmentally relevant mercury concentrations on chick survival, our results concur with the small number of previous field studies that have not been able to detect reduced survival in the wild.

Acuna, S., D.F. Deng, P. Lehman, and S. Teh (2012). "Sublethal dietary effects of Microcystis on Sacramento splittail, Pogonichthys macrolepidotus." Aquatic Toxicology 110-111 (2012): 8.

Acuña, S. C., D. V. Baxa, et al. (2010). Dietary effects of Microcystis aeruginosa on threadfin shad, Dorosoma petenense. IEP 2010 Annual Workshop and the 6th Biennial Bay-Delta Science Conference. Workshop presentation at the California State University, Sacramento and the Sacramento Convention Center, Sacramento, CA.

In the San Francisco Estuary (SFE), the presence of the toxic algal bloom Microcystis aeruginosa has been suggested as a link to the Pelagic Organism Decline (POD) by the Interagency Ecology Program (IEP) (2005). The bloom is predominantly of the microcystin LR strain (MC-LR), a hepatotoxic protein that may impact the survival of fish. The purpose of this study was to determine whether toxins from M.

aeruginosa collected from the SFE were toxic to POD species, such as threadfin shad, Dorosoma petenense (TFS) and to use the biomarkers of exposure to link toxicity to exposure in field samples from the SFE. Juvenile TFS, were exposed to diets containing 5 (D5) and 10 (D10) µg/g MC-LR for 57 days. The treatments were compared to the control diet, 0 µg/g MC-LR (D0). Preliminary results revealed that condition factor (CF) and liver and gonadal lesions were sensitive to exposure. There was a significant inverse relationship with CF and MC-LR, with exposed fish exhibiting severe cachexia. Liver lesions of sinusoidal congestion, and glycogen depletion significantly increased with increasing MC-LR concentrations, indicating hemorrhaging in the liver and poor nutritional status, respectively. In females, there was a significant increase in severe ovarian atresia with increasing MC-LR concentration, indicating loss of reproductive potential. The results indicate that chronic exposure to MC-LR from M. aeruginosa significantly impairs the health and reproductive potential of threadfin shad. The biomarkers characterized from the dietary study will be compared with field samples of TFS from the SFE collected during M. aeruginosa blooms to determine whether the TFS were exposed to MC-LR. The results from this study may help establish the link suggested by the IEP between the bloom and POD therefore aiding in determining management protocols for controlling the M. aeruginosa blooms in the SFE.

Adams, P. (2010). Advances in salmonid monitoring: The California coastal salmonid population monitoring plan and the salmon monitoring advisor. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Without salmon monitoring, we can not know what condition salmon populations are in and whether our actions are helping or harming these populations. This talk describes two recent advances in salmonid monitoring: The California Coastal Salmonid Population Monitoring Plan and The Salmon Monitoring Advisor website. The California Coastal Salmonid Monitoring Plan has been developed to gauge the condition and recovery of coastal salmonids and uses the Viable Salmonid Population concept; abundance, productivity, spatial structure, and diversity; as a framework. It divides California into Northern and Southern areas with a boundary north of the Pajaro River. In the Northern Area, adult numbers will be estimated mostly through expanded redd survey selected in a random, spatially balanced way, and in the Southern Area, adults will be counted at fixed stations due to different species composition and extreme low abundance. Spatial structure will be monitored using juvenile summer-fall snorkel surveys. Diversity traits are locally different, and will need to be examined using local diversity monitoring plans. A second project is the web-accessible knowledge base called the "Salmon Monitoring Advisor". The site is accessible in a hierarchical manner to reflect diverse audiences, including (1) scientists who design monitoring programs and/or analyze the resulting data, (2) technical staff who implement monitoring designs in the field, (3) people involved in providing funding for monitoring programs, and (4) managers and decision makers. It provides advice and guidelines of how to work through the essential steps involved in designing monitoring programs to meet objectives. It provides pros and cons of different designs, rather than being prescriptive about which design best meets a particular monitoring objective. The web site uses seven sequential steps to guide monitoring design and implementation and provides extensive explanations and real-world examples for each step.

Adams, P. B., L. W. Botsford, et al. (2007). "Coho Salmon Are Native South of San Francisco Bay: A Reexamination of North American Coho Salmon's Southern Range Limit." Fisheries 32(9): 441.

Kaczynski and Alvarado (2006) have challenged the established southern boundary of coho salmon (Oncorhynchus kisutch) at the San Lorenzo River. They conclude that it is improbable coho salmon maintained self-sustaining populations south of San Francisco Bay, based primarily on evidence from early museum collections and literature, the archaeological record, analyses of ocean conditions, and suitability of habitat. They suggest that hatchery plantings were the source of these coho salmon south of San Francisco Bay. Using the same and new information, we are able to counter these statements. Our examination of existing records found no reason to discount the coho salmon collections made in 1895 from streams south of San Francisco. Early distributional records state that coho salmon were abundant

from San Francisco northward, but did not indicate coho salmon were absent south of San Francisco. Recent archeological evidence documents the presence of coho salmon in middens south of San Francisco prior to European habitation of the region. Furthermore, we found no creditable climatic, oceanographic, or ecological evidence for habitat differences between areas immediately north and south of San Francisco Bay. In fact, we believe that there is a more reasonable habitat and faunal break south of the San Lorenzo River, encompassing the allegedly controversial southern range of the coho salmon.Original Abstract: Kaczynski y Alvarado (2006) establecieron que el Rio San Lorenzo es la frontera sur de la distribucion del salmon coho (Oncorhynchus kisutch). Sobre la base de evidencia museografica y documentaria, registros arqueologicos, analisis de condiciones oceanicas y del habitat, concluyen que es improbable que existan poblaciones viables de salmon coho al sur de la Bahia de San Francisco. Sugieren que el origen de estos salmones en la Bahia de San Francisco son granjas de engorda. Utilizando la misma y nueva informacion, en el presente trabajo se confrontan dichos argumentos. Nuestro examen de los registros existentes mucstra que no hay razon aparente como para descartar las colecciones de salmon coho realizadas en 1895 en los rios del sur de San Francisco. Los primeros registros de la distribucion geografica de esta especie indican que era abundante desde San Francisco hacia el norte, pero no prueban que el salmon coho estuviese ausente del sur de San Francisco. La evidencia arqueologica recicnte documenta la presencia del salmon coho en el sur de San Francisco incluso antes de los asentamientos europeos en la region. Mas aun, no se encontro evidencia suficiente en cuanto al clima, oceanografia o ecologia que corrobore diferencias de habitat cntre las areas inmediatas al sur y norte de la Bahia de San Francisco. De hecho, creetmos que existe una mayor y razonable diferenciacion faunistica y de habitat at sur del Rio San Lorenzo, lo que comprende buena partc de la controversia sobre el ambito sureno de la distribucion del salmon coho.

Adib-Samii, J. (2010). 2009 Spring Kodiak Trawl Survey for the San Francisco Estuary. IEP Newsletter. 23: 5.

Adib-Samii, J. (2010). 2010 Smelt Larva Survey. IEP Newsletter. 23: 4.

Adib-Samii, J. (2010). The presence and relative abundance of delta smelt in the Sacramento Deep Water Shipping Channel. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Agency, U. S. E. P. (2013). Watershed Modeling to Assess the Sensitivity of Streamflow, Nutrient, and Sediment Loads to Potential Climate Change and Urban Development in 20 U.S. Watersheds, Second Draft. U. S. E. P. Agency. Washington, DC, U.S. Environmental Protection Agency: 186.
This report describes watershed modeling in 20 large, U.S. drainage basins (6,000-27,000 mi2) to
characterize the sensitivity of U.S. streamflow, nutrient (N and P) loading, and sediment loading
to a range of potential mid-21st century climate futures, to assess the potential interaction of
climate change and urbanization in these basins, and to improve our understanding of methodological challenges associated with integrating existing tools (e.g., climate models,
downscaling approaches, and watershed models) and datasets to address these scientific
questions. Study areas were selected to represent a range of geographic, hydroclimatic,
physiographic, and land use conditions together with practical considerations such as the
availability of data to calibrate and validate watershed models. Climate change scenarios are
based on mid-21st century climate model projections downscaled with regional climate models
(RCMs) from the North American Regional Climate Change Assessment Program (NARCCAP) and the bias-corrected and spatially downscaled (BCSD) data set described by Maurer et al.

(2007). Urban and residential development scenarios are based on EPA's national-scale
Integrated Climate and Land Use Scenarios (ICLUS) project (U.S. EPA, 2009d). Watershed
modeling was conducted using the Hydrologic Simulation Program-FORTRAN (HSPF) and Soil
and Water Assessment Tool (SWAT) watershed models.

Aguado, E., D. Cayan, et al. (1992). "Climatic fluctuations and the timing of west-coast streamflow." Journal of Climate 5(12): 1468-1483.

Since about 1950 there has been a trend in the California Sierra Nevada toward a decreasing portion of the total annual streamflow occurring during April through July, while the streamflow during autumn and winter has increased. This trend not only has important ramifications with regard to water management, it also brings up the question of whether this represents a shift toward earlier release of the snowpack resulting from greenhouse warming. Therefore, the observed record has been examined in terms of relative influences of temperature and precipitation anomalies on the timing of streamflow in this region. To carry out this study, the fraction of annual streamflow (called the fractional streamflow) occurring in November-January (NDJ), February-April (FMA), and May-July (MJJ) at low, medium, and high elevation basins in California and Oregon was examined. Linear regression models were used to relate precipitation and temperature to the fractional streamflow at the three elevations for each season. Composites of monthly temperature and precipitation were employed to further examine the fractional streamflow in its high and low tercile extremes. Long time series of climatic and hydrologic data were also looked at to infer the causes in the trend toward earlier runoff. For the low-elevation basins, there is a dominant influence of precipitation on seasonal fractional streamflow. Middle-elevation basins exhibit a longer memory of precipitation and temperature in relation to their fractional streamflow. In-season precipitation is still the most important influence upon NDJ and FMA fractional streamflow; however, the influence of temperature in melting the snowpack is seen on MJJ fractional streamflow, whose strongest influence is FMA temperature. At higher elevations, prior-season precipitation exerts a greater influence than at low and middle elevations, and seasonal temperature anomalies have an effect on all seasonal streamflow fractions. There are several causes for the trend toward decreasing fractional streamflow in the spring and summer. Concomitant with the trend in the timing of streamflow was an increase in NDJ (most notably November) precipitation. There also has been a trend toward higher spring temperatures over most of the western United States, but since there has also been a trend toward decreasing temperatures in the southeast, we do not interpret this as a signal of anthropogenic warming. Other factors in the trend toward earlier streamflow may include a decrease in MJJ precipitation and an increase in August-October precipitation.

Ahearn, D. S., R. W. Sheibley, et al. (2005). "Effects of river regulation on water quality in the lower Mokelumne River, California." River Research and Applications 21(6): 651-670.

This study examines the effects of flow regulation on water quantity and quality by comparing an impounded system (Mokelumne River) with an adjacent unimpounded system (Cosumnes River). Between 1999 and 2002, the Cosumnes River displayed a strong seasonal cycle for each constituent analysed (total suspended solids, NO3-N, total nitrogen, PO4-P, total phosphorus, dissolved silicon, specific conductivity, flow), while reservoirs in the lower Mokelumne buffered and attenuated physical and chemical fluctuations creating a weak seasonal pattern. Dissolved silicon and total suspended solids were the two constituents most efficiently sequestered by the reservoirs. While the reservoirs acted as traps for most constituents, NO3-N and PO4-P were produced during the drier years of the study, 2001 and 2002. In contrast, the unimpounded reference reach in the Cosumnes was an annual source for all constituents measured. The Cosumnes delivers its highest NO3-N concentrations during the winter months (December-April), while peak concentrations in the Mokelumne occur during the snowmelt (May-July) and baseflow (August-November) seasons. Due to downstream N-limitation, this temporal shift in NO3-N export may be contributing to accelerated algal growth in the reach immediately downstream and

eventually to algal biomass loading to the downstream Sacramento-San Joaquin Delta. Copyright (c) 2005 John Wiley & Sons, Ltd.

Aiona, A. (2010). Flows in the Delta, Water Years 2008 and 2009. IEP Newsletter. 23: 2.

Alabaster, J. S. (1989). "The dissolved oxygen and temperature requirements of king salmon Oncorhynchus tshawytscha in the San Joaquin Delta, California, USA." Journal of Fish Biology 34(2): 331-332.

Albrecht, A. B. (1964). "Some observations on factors associated with survival of striped bass eggs and larvae." California Fish and Game 50: 100-113.

Alexander, R. R., R. J. Stanton, et al. (1993). "Influence of sediment grain size on the burrowing of bivalves: Correlation with distribution and stratigraphic persistence of selected Neogene clams." Palaios 8(3): 289-303.

Burrowing ability of 21 species of clams from Oregon, New Jersey, and Scotland was determined in each sieved sediment ranging from fine gravel to mud in half phi increments. A burrowing rate index (BRI), which normalizes burrowing time for specimen mass, was calculated for each species in each sediment. Skewness and kurtosis of the profile of average BRI's across the range of grain sizes was used to categorize species as substrate generalists, substrate sensitive, or substrate specialists. Substrate generalists (Anadara ovalis, Mercenaria mercenaria, Astarte sulcata, Venerupis decussata, Venus striatula, Venus casina, Mya arenaria) burrowed slowly into a wide range of grain sizes. Burrowing rate gradually diminished in progressively coarser and finer grained sediments away from the optimum grain size, producing a platykurtic (genty arching) BRI profile. Substrate specialists (Spisula solida, Nucula sulcata, Cardium edule, Abra alba, Cultellus pellucidus) burrowed rapidly in a very limited range of grain sizes, but failed to burrow into either or both grain size extremes, thereby producing leptokurtic (peaked) BRI profiles. Substrate sensitive species (Donax variabilis, D. vittatus, Tellina (Angulus) tenuis, Ensis directus, Clinocardium nuttalli, Protothaca staminea, Petricola pholadiformis, Macoma nasuta, Scrobicularia plana) penetrated a wider range of grain sizes than specialists, although burrowing rates are slower at the coarse textured extreme in comparison to generalists. In San Francisco Bay and Mississippi Delta habitats, generalists (Anadara, Mercenaria, Mya) occur commonly in most sediment categories and show high mean percent occurrence and low coefficient of variation from the seven and eight sediment-influenced molluscan communities, respectively. Substrate specialists (Spisula, Nucula) and some sensitive taxa (e.g., Petricola) are sediment-restricted, show fidelity to one or two communities, have low mean percent occurrence, and high coefficient of variation. Substrate generalists (Anadara trilineata, Mya arenaria,), and species transitional with generalists (Macoma nasuta), based on experimental data on either conspecific or congeneric individuals, show high mean percent occurrences and low coefficient of variation in the Pliocene Pecten Zone communities of the San Joaquin Formation of the Kettleman Hills, California. Generalists show stratigraphic persistence, i.e., they are found in 12-14 of 20 successive biostratigraphic units in the Etchegoin and San Joaquin Formations, whereas specialists (Spisula, Acila (Nucula)) are never found in more than four biostratigraphic units.

Allen, S. G. (1991). Harbor seal habitat restoration at Strawberry Spit, San Francisco Bay: 47.

The shoreline habitat preferred by harbor seals (Phoca vitulina) has been shrinking at an accelerated rate in the past century. Strawberry Spit is one of twelve documented seal haul-out sites in San Francisco Bay and is an example of the abandonment of a haul-out site presumably due to increased development pressures. Harbor seals have been hauling out on Strawberry Spit since the late 1960s. It was estimated that the number of seals using the Spit during the winter of 1975-76 represented approximately one third of the total estimated harbor seal population of San Francisco Bay at the time, roughly 100 seals. In the late 1970s, Strawberry Spit was designated for a development project. Since then, the number of seals has dropped precipitously. To mitigate potential disturbance to wildlife, the developer agreed to sever the Spit from the mainland to create a seal refuge. The study was

designed to evaluate the efficiency of mitigation measures and to provide recommendations on the value of such measures in enhancing seal habitat.

Allen, S. G., M. Stephenson, et al. (1993). "Red-pelaged harbor seals of the San Francisco Bay region." Journal of Mammalogy 74(3): 588-593.
Harbor seals of San Francisco Bay, California, have a higher incidence of red pelage (range, 4-32% of the total count) than is observed along the outer eastern-Pacific coast or elsewhere in the world. Red pelage was observed among all sex and age classes, except for pups. The pattern of red coloration on the body varied; most seals had red hair extending from the head down to the shoulder. Elemental analyses of hair samples revealed that red coloration was from deposition of iron oxide precipitates on the hair shaft. We postulate that the particular conditions within San Francisco Bay, including large areas of shallow water and strong summer winds with resuspension of sediments, bring sufficient quantities of ferrous iron from the sediments into the water column where it may serve as a principal source of the ferric oxide deposited on pelage of seals.

Alpert, P., F. T. Griggs, et al. (1999). "Riparian forest restoration along large rivers: Initial results from the Sacramento River Project." Restoration Ecology 7(4): 360-368.
Restoration of riparian vegetation along large rivers is complicated by the patchiness of the habitat and by conflicts with the societal need to control flooding. The Sacramento River Project, led by The Nature Conservancy in northern California, is testing whether it is possible to restore native forest along a large river without removing flood control. We conducted a post-hoc analysis of monitoring data collected by the project on 1-4-year old plantings of 10 native trees and shrubs at five sites. Two questions of general interest were: Can one identify types of species or sites that are especially suitable for restoration in such riparian habitats? To what degree must sites be treated as mosaics of patches, with different types of patches that are suited to different species? Plant performance as measured by height was better in species of Salicaceae or in species planted as cuttings than in species of other families or in species planted as seedings or seeds. Three within-site factors, land form, soil depth to a buried layer of sand or gravel, and soil texture, affected the growth of several species, indicating that sites do need to be treated as patchy. However, there was little evidence that different species performed better on different types of patches. Instead, areas with deep or fine soils seemed to be favorable for a number of species. Results suggest that it is feasible to re-establish native trees and shrubs along large, regulated rivers, at least at certain sites for an initial period of several years with the aid of weed control and irrigation. Shallowly buried layers or lenses of gravel or sand are a hidden, fine-scale factor that can reduce plant growth on river terraces.

Alpine, A. E., and J. E. Cloern. (1992). "Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary." Limnology and Oceanography 37(5): 946-955.
The recent invasion of San Francisco Bay by the suspension-feeding clam Potamocorbula amurensis has provided an opportunity to document the ecological consequences of a major biological disturbance. Previous work over the last two decades has shown that phytoplankton biomass in the upper estuary is low (2-3 mg Chl a m-3) during seasonal periods of high river flow and short residence times, and it is usually high (peak>30 mg Chl a m-3) during the summer-autumn seasons of low river flow and long residence time. However since P. amurensis became widespread and abundant in 1987, the summer phytoplankton biomass maximum has disappeared, presumably because of increased grazing pressure by this newly introduced species. For the period 1977-1990, mean estimated primary production was only 39 g C m-2 yr-1 during years when bivalve suspension feeders were abundant (>2,000 m-2), compared to 106 g C m-2 yr-1 when bivalves were absent or present in low numbers. These observations support the hypothesis that seasonal and interannual fluctuations in estuarine phytoplankton biomass and primary production can be regulated jointly by direct physical effects (e. g. river-driven transport) and trophic interactions (episodes of enhanced grazing pressure by immigrant populations of benthic suspension feeders).

Alpine, A. E. and J. E. Cloern (1985). "Differences in in-vivo fluorescence yield between three phytoplankton size classes." Journal of Plankton Research 7(3): 381-390.
The size-dependent relationship between in vivo fluorescence (IVF) and chlorophyll a was determined for monthly phytoplankton samples from the San Francisco Bay estuary. Chlorophyll a and IVF were both measured on netplankton (>22 pm), nanoplankton (5 22 pm), and ultraplankton (<5 prn) samples that were separated with screens. IVF and chlorophyll a were linearly related for each size class, but the IVF per unit chlorophyll a (R) was significantly different between these three size classes. The ultraplankton R was twice that of the nanoplankton which was in turn twice the netplankton R. Hence, accurate size fractionation of phytoplankton biomass from measures of IVF requires correction for size-dependent variations in R.

Alpine, A. E. and J. E. Cloern (1988). "Phytoplankton growth rates in a light-limited environment, San Francisco Bay." Marine Ecology Progress Series 44(2): 167-173.
San Francisco Bay has a high degree of spatial variability in physical properties (e.g. suspended sediment concentrations, water depths, vertical mixing rates) that affect biological processes. We used this setting to test the hypothesis that light availability is the primary control of phytoplankton growth in this turbid nutrient-rich estuary. In situ incubations (24 h), designed to simulate vertical mixing over the water column at 2 rates, were done at 4 sites. The photic depth to mixed depth ratio (Zp:Zm) at the 4 sites ranged from 0.12 to 1.1. Phytoplankton growth rates were estimated by 14C assimilation and by changes in cell number. Growth rates were highest (approximately 2 divisions d-1) where the photic depth was large relative to the mixed depth, and small or negalive where Zp:Zm was small. Growth rate increased with total daily light exposure and fit a hyperbolic function that predicts maximum specific growth rate of about 2 divisions d-1 and a compensation irradiance of about 1.4 Einst. m-2 d-1.

Alpine, A. E. and J. E. Cloern (1992). "Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary." Limnology and Oceanography 37: 946-955.
The recent invasion of San Francisco Bay by the suspension-feeding clam Potamocorbula amurensis has provided an opportunity to document the ecological consequences of a major biological disturbance. Previous work over the last two decades has shown that phytoplankton biomass in the upper estuary is low (2-3 mg Chl a m super(-3)) during seasonal periods of high river flow and short residence time, and it is usually high (peak > 30 mg Chl a m super(-3)) during the summer-autumn seasons of low river flow and long residence time. However since P. amurensis became widespread and abundant in 1987, the summer phytoplankton biomass maximum has disappeared, presumably because of increased grazing pressure by this newly introduced species. For the period 1977-1990, mean estimated primary production was only 39 g C m super(-2)/yr during years when bivalve suspension feeders were abundant (> 2,000 m super(-2)), compared to 106 g C m super(-2)/yr when bivalves were absent or present in low numbers. These observations support the hypothesis that seasonal and interannual fluctuations in estuarine phytoplankton biomass and primary production can be regulated jointly by direct physical effects and trophic interactions.

Ambler, J. W., J.E. Cloern, and A. Hutchinson (1985). "Seasonal cycles of zooplankton from San Francisco Bay." Hydrobiologia 129: 177-197.
The two estuarine systems composing San Francisco Bay have distinct zooplankton communities and seasonal population dynamics. In the South Bay, a shallow lagoon-type estuary, the copepods Acartia spp. and Oithona davisae dominate. As in estuaries along the northeast coast of the U.S., there is a seasonal succession involving the replacement of a cold-season Acartia species (A. clausi s.l.) by a warm-season species (A. californiensis), presumably resulting from the differential production and hatching of dormant eggs. Oithona davisae is most abundant during the fall. Copepods of northern San Francisco Bay, a partially-mixed estuary of the Sacramento-San Joaquin Rivers, organize into discrete populations according to salinity distribution: Sinocalanus doerrii (a recently introduced species) at the riverine boundary, Eurytemora affinis in the oligohaline mixing

zone, Acartia spp. in polyhaline waters (18–30%), and neritic species (e.g., Paracalanus parvus) at the seaward boundary. Sinocalanus doerrii and E. affinis are present year-round. Acartia clausi s.l. is present almost year-round in the northern reach, and A. californiensis occurs only briefly there in summer-fall. The difference in succession of Acartia species between the two regions of San Francisco Bay may reflect differences in the seasonal temperature cycle (the South Bay warms earlier), and the perennial transport of A. clausi s.l. into the northern reach from the seaward boundary by nontidal advection. Large numbers (>106 m−3) of net microzooplankton (>64 μm), in cluding the rotifer Synchaeta sp. and three species of tintinnid ciliates, occur in the South Bay and in the seaward northern reach where salinity exceeds about 5–10 % Maximum densities of these microzooplankton are associated with high concentrations of chlorophyll. Meroplankton (of gastropods, bivalves, barnacles, and polychaetes) constitute a large fraction of zooplankton biomass in the South Bay during winter-spring and in the northern reach during summer-fall.

Anderson, B., J. Hunt, et al. (2007). "Patterns and trends in sediment toxicity in the San Francisco Estuary." Environmental Research 105(1): 145-155.
Widespread sediment toxicity has been documented throughout the San Francisco Estuary since the mid-1980s. Studies conducted in the early 1990s as part of the Bay Protection and Toxic Cleanup Program (BPTCP), and more recently as part of the Regional Monitoring Program (RMP) have continued to find sediment toxicity in the Estuary. Results of these studies have shown a number of sediment toxic hotspots located at selected sites in the margins of the Estuary. Recent RMP monitoring has indicated that the magnitude and frequency of sediment toxicity is greater in the winter wet season than in the summer dry season, which suggests stormwater inputs are associated with sediment toxicity. Additionally, spatial trends in sediment toxicity data indicate that toxic sediments are associated with inputs from urban creeks surrounding the Estuary, and from Central Valley rivers entering the northern Estuary via the Delta. Sediment toxicity has been correlated with a number of contaminants, including selected metals, PAHs and organochlorine pesticides. While toxicity identification evaluations (TIEs) suggest that metals are the primary cause of sediment toxicity to bivalve embryos;,TIEs conducted with amphipods have been inconclusive. (c) 2006 Elsevier Inc. All rights reserved.

Anderson, B. S., J. W. Hunt, et al. (2000). "Ecotoxicologic change at a remediated Superfund site in San Francisco, California, USA." Environmental Toxicology and Chemistry 19(4): 879-887.
Lauritzen Channel is an industrial waterway adjacent to the former United Heckathorn facility in the inner Richmond Harbor area of San Francisco Bay, California, USA. Marine sediments at this Superfund site were dredged from late 1996 through early 1997 to remove the primary chemicals of concern: DDT, and dieldrin. This study assessed the Lauritzen Channel marine environment immediately before and approximately one year after the dredging of sediments. The study included chemical analysis of sediments, tissue concentrations of transplanted mussels, toxicity testing of sediment samples, and characterization of benthic community structure. Results indicated that sediment toxicity to bivalve larvae (Mytilus galloprovincialis) decreased in postremediation samples, but that toxicity to the amphipod Eohaustorius estuarius increased significantly. Assessment of benthos at this site suggested a transitional benthic community structure. In addition, postremediation sediments remained contaminated by a variety of organic chemical compounds, including DDT, dieldrin, chlordane, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls. Tissue concentrations of DDT and dieldrin in mussels (M. galloprovincialis) were lower than those in preremediation samples, indicating that although sediment concentrations of organochlorine pesticides remained high, concentrations of these chemicals in the water column were reduced after dredging. This study demonstrates that the components of the site assessment were useful in determining effectiveness of the remediation activities.

Anderson, F., M. Detto, J. Verfaillie, J.F. Saraceno, D. Baldocchi, B.A. Bergamaschi, and R. Fuji (2010). Rebuilding Delta soils: the balance of greenhouse gases. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Efforts to restore and convert wetlands on deeply subsided Delta peat islands hold many environmental benefits such as subsidence reversal, soil carbon storage, and atmospheric carbon sequestration. Although these ecosystems can store carbon dioxide (CO_2) or limit the oxidation of existing peats, the anaerobic conditions created by permanent and semi-permanent flooding can result in the release of methane (CH_4), a more potent greenhouse gas. The USGS Carbon Group, Sacramento and UC Berkeley Biometeorology group are conducting studies to measure CO_2 and CH_4 emissions from two types of wetland restoration management strategies to rebuild soils on existing agricultural peatlands: (1), conversion to rice cultivation, and (2), conversion to a continuously inundated wetland. Quasi-continuous measurements utilizing eddy covariance for CO_2 and CH_4 were conducted on Twitchell Island above rice cultivation plots in 2009 and above a restored wetland marsh in 2010. Preliminary results suggest that rice cultivation can be a strong sink for CO_2, due to high rates of photosynthesis during the day and the inhibition of CO_2 released at night as respiration is limited by the flooded conditions. CH_4 emissions were lower than expected, but still about two times the amount compared to the CH_4 measurements collected from a pasture located on Sherman Island. The lower than expected CH_4 emissions may be due to the fact that 2009 was the first year of cultivation and there is a lack of an established methanogenic bacteria community and/or a suitable substrate of labile carbon. Initial results from the restored wetland are similar to the rice cultivation plots and have the potential to be a strong sink for CO_2. However, CH_4 fluxes are expected to be higher as conditions for methanogenesis most likely exist after ten years of vegetative growth since the wetland was established.

Anderson, J., F. Bombardelli, K. Zamani, E. Ateljevich, and P. Luzuriga (2010). Development of a sediment and transport module for the DSM2 Delta Simulation Model. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

This poster describes the development of a one-dimensional Sediment and Transport Module (STM) for the DSM2 Delta Simulation Model. STM is a general transport model for conservative and non-conservative constituents with special attention to including sediment transport. The module represents cohesive and non-cohesive sediment transport in tidal channel networks. Both suspended sediment and bed load are included in the module. STM uses a static frame of reference (Eulerian) which will complement the existing moving frame of reference (Lagrangian) DSM2 water quality module, QUAL. STM uses a second order accurate, finite volume numerical solution approach. To verify that components of the model are coded properly, a companion testing code has been developed. A Technical Advisory Committee meets twice a year to guide the model development. Additionally, a website is being developed that provides links to available sediment data sources for the Sacramento-San Joaquin Delta. This poster will describe the progress and future directions for developing STM and applying it for sediment transport in the Delta.

Anderson, J., B. Rook, C. Watry, J. Hannon, and J. Merz (2010). Evaluating a spawning habitat enhancement project: Restoring ecological processes and improving habitat quality to benefit native salmonids. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

We evaluated the effects of spawning gravel augmentation on habitat conditions for Chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (O. mykiss) in the lower American River. A site with a high potential for anadromous fish spawning use was selected for habitat enhancement on a regulated portion of the lower American River. Cleaned and sorted gravel material from local floodplain tailings were utilized to augment and improve existing riffle habitat conditions by decreasing average depths and substrate size while increasing average velocities. We employed a Before-After, Control-Impact (BACI) design structure to test differences between un-enhanced and enhanced areas (i.e., Control-Impact) by subjecting these areas to replicated sampling over time (i.e., Before-After). We used the following metrics to assess the effectiveness of the implemented augmentation on local salmonid populations: 1) changes in habitat quality (i.e., substrate composition and hyporheic water quality); and, 2) habitat use (i.e., spawning and rearing) versus availability. Placed gravel was composed of appropriately sized substrate for

spawning salmonids in the lower American River. Chinook salmon spawning was observed within six weeks, and steelhead trout spawning was subsequently documented at the enhanced site in the first season following augmentation. Juvenile salmonid rearing was significantly higher along stream margins and inundated floodplain habitats adjacent to enhanced habitat areas. These results suggest that newly created riffle habitat can produce immediate ecosystem benefits and demonstrate rapid biological responses. Continued success depends upon the integration of future projects at the reach scale to adaptively manage existing and proposed projects to achieve programmatic goals and objectives.

Anderson, J. (2010). Salinity in the San Francisco Bay and Delta, Water Years 2008 and 2009. IEP Newsletter. 23: 2.

Anderson, J., F. Chung, et al. (2008). "Progress on incorporating climate change into management of California's water resources." Climatic Change 87: S91-S108.
This paper presents preliminary efforts by agencies managing California's water resources to incorporate climate change research into their planning and management tools. Projected increases in air temperature may lead to changes in the precipitation patterns, runoff timing and volume, sea level rise, and changes in the amount of irrigation water needed due to modified evapotranspiration rates. Historical observations of climate change related to California's water resources are shown. Results from preliminary modeling studies of potential impacts of climate change to operations of the State Water Project and Central Valley Project, Delta water quality and water levels, flood forecasting and evapotranspiration rates are presented. Future directions to incorporate risk assessment are discussed.

Anderson, L. and M. C. Hoshovsky. (2000). Egeria densa. Invasive Plants of California's Wildlands. C. C. Bossard, J. M. Randall and M. C. Hoshovsky. Berkeley, CA., University of California Press.

Anderson, M. (2010). Planning for water resources system re-operation due to climate change. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Climate change is expected to increase temperatures, change the distribution and form of precipitation, and change the timing and quantity of runoff. All of these changes will impact California’s water resources systems demanding some form of adaptation. Changing water management practices is a centerpiece of the California Department of Water Resources’ adaptation strategies for climate change. In this talk, a review of climate change impacts affecting California’s water resources is provided as a backdrop for setting the landscape for system re-operation as a means of adapting to those changes.

Antonio, D. B., C. Swanson, et al. (2000). "Prevalence of Mycobacterium in wild and captive delta smelt." California Fish and Game 86(4): 233-243.

Anttila, C. K., C. C. Daehler, et al. (1998). "Greater male fitness of a rare invader (Spartina alterniflora, Poaceae) threatens a common native (Spartina foliosa) with hybridization." American Journal of Botany 85(11): 1597-1601.
Hybridization with abundant invaders is a well-known threat to rare native species. Our study addresses mechanisms of hybridization between a rare invader, smooth cordgrass (Spartina alterniflora) and the common native California cordgrass (S. foliosa) in the salt marshes of San Francisco Bay. These species are wind-pollinated and flower in summer. The invader produced 21-fold the viable pollen of the native, and 28% of invader pollen germinated on native stigmas (1.5-fold the rate of the native's own pollen). Invader pollen increased the seed set of native plants almost eightfold over that produced with native pollen, while native pollen failed to increase seed set of the invader. This pollen swamping and superior siring ability by the invader could lead to serial genetic assimilation of a very large native population. Unlike California cordgrass, smooth cordgrass can grow into low intertidal habitats and cover open mud necessary to foraging shorebirds, marine life, navigation, and flood control in channels. To the extent that intertidal range of the hybrids is more similar to the invader than to the native parent,

introgression will lead to habitat loss for shore birds and marine life as well to genetic pollution of native California cordgrass.

Anttila, K. C., A. R. King, et al. (2000). "Reciprocal hybrid formation of Spartina in San Francisco Bay." Molecular Ecology 9(6): 765-770.
Diversity in the tRNA super(LEU1) intron of the chloroplast genome of Spartina was used to study hybridization of native California cordgrass, Spartina foliosa, with S. alterniflora, introduced to San Francisco Bay approximately 25 years ago. We sequenced 544 bases of the tRNA super(LEU1) intron and found three polymorphic sites, a pyrimidine transition at site 126 and transversions at sites 382 and 430. Spartina from outside of San Francisco Bay, where hybridization between these species is impossible, gave cpDNA genotypes of the parental species. S. foliosa had a single chloroplast haplotype, CCT, and this was unique to California cordgrass. S. alterniflora from the native range along the Atlantic coast of North America had three chloroplast haplotypes, CAT, TAA, and TAT. Hybrids were discriminated by random amplified polymorphic DNA (RAPD) phenotypes developed in a previous study. We found one hybrid that contained a cpDNA haplotype unknown in either parental species (TCT). The most significant finding was that hybridization proceeds in both directions, assuming maternal inheritance of cpDNA; 26 of the 36 hybrid Spartina plants from San Francisco Bay contained the S. foliosa haplotype, nine contained haplotypes of the invading S. alterniflora, and one had the cpDNA of unknown origin. Furthermore, cpDNA of both parental species was distributed throughout the broad range of RAPD phenotypes, suggesting ongoing contributions to the hybrid swarm from both. The preponderance of S. foliosa cpDNA has entered the hybrid swarm indirectly, we propose, from F1s that backcross to S. foliosa. Flowering of the native precedes by several weeks that of the invading species, with little overlap between the two. Thus, F1 hybrids would be rare and sired by the last S. foliosa pollen upon the first S. alterniflora stigmas. The native species produces little pollen and this has low viability. An intermediate flowering time of hybrids as well as pollen that is more vigourous and abundant than that of the native species would predispose F1s to high fitness in a vast sea of native ovules. Thus, spread of hybrids to other S. foliosa marshes could be an even greater threat to the native species than introductions of alien S. alterniflora.

Aplin, J. A. (1967). Biological survey of San Francisco Bay, 1963-1966. MRO Reference 67-4, California Department of Fish and Game Marine Resources Operations Laboratory.

Archbald, G., and K. Boyer (2010). Evaluating the potential for spread of an invasive forb, Limonium ramosissimum, in San Francisco Bay Salt Marshes. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Because invasive plants threaten San Francisco Bay’s restored and historic salt marsh communities, identifying the extent of new invasions and how the potential for additional spread is affected by physical factors will help managers prioritize invasive species for control. In 2007, Limonium ramosissimum ssp provinciale populations were discovered in South S.F. Bay marshes. While invasive in southern California marshes, the extent of the invasion in S.F. Bay marshes, and how salinity and inundation stress at the marsh and estuary scale affects the plant’s dispersal, establishment, growth and reproduction, is unknown. To determine invasion extent, marshes were searched and Limonium was mapped with GPS. To test dispersal potential, Limonium seeds were floated in aquaria of different salinities for up to 14 days and then germinated in fresh water. To test how salinity affects establishment, seeds of Limonium and 3 common marsh species were germinated in salinities from 0 to 45. To test how common stressors effect growth and reproduction, Limonium plants were grown from seeds to flowering under crossed inundation and salinity treatments in a greenhouse experiment. Results indicate Limonium has established in at least 15 marshes in S. SF Bay, covering approximately 3 acres. Limonium seeds can float in 15 and 30 salinity aquaria for at least two weeks, and then germinate in fresh water (~86%) regardless of salinity or time floating. When tested under saline conditions, Limonium seeds germinated at rates equal to common native marsh species at 0, 15, 30 and 45 salinity. When Limonium was grown under crossed salinity/inundation treatments, both factors independently

affected growth and flowering. Taken together, these results suggest Limonium is capable of long distance dispersal events, can establish as readily as common native halophytes, and invasions rates will accelerate if populations spread to low salinity marshes. Limonium's invasion potential warrants early removal.

Arkush, K. D., and P.A. Siri (2001). Exploring the role of captive broodstock programs in salmon restoration. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 319-330.

Severe population declines have occurred in many Pacific salmon stocks. Stock declines have been attributed to both anthropogenic and natural environmental causes. These declines have been so dramatic that resource agencies have not had the time or means to quantitatively describe stocks and develop rapid, reliable methods of conserving rare genes. One method to prevent extinction is gene banking by means of rearing broodstock in captivity for use in supplementing rare and endangered stocks. With varying degrees of success, several captive breeding programs have been initiated to provide "insurance" against genetic loss of imperiled stocks. Captive breeding is expensive, requiring long-term intensive fish husbandry. It is not an alternative to habitat restoration. In certain situations, such as small runs (20 to 100 spawning adults) combined with habitat undergoing restoration, captive breeding may be a desirable supplementation strategy. It is certainly a beneficial option for any stock on the edge of extinction. There are several salmon captive broodstock programs on the west coast of North America, each employing different approaches and technologies. Captive breeding techniques are evolved to a point where the progeny of wild fish can be reared with a high degree of success. However, this kind of intervention is costly and must be weighed against other factors that will determine stock recovery. It is incumbent upon managers and scientists to define the uncertainty, or risk, of captive breeding. Risk assessment is an essential component of any captive breeding program. Emerging captive breeding programs can benefit from the range of experience and technological development that has evolved over the past decade. Molecular genetics, captive broodstock technology, conservation biology, and fisheries supplementation risk assessment have matured to a stage where salmonid captive breeding can be planned as an intervention with a measured effect.

Arkush, K. D., A. R. Giese, et al. (2002). "Resistance to three pathogens in the endangered winter-run chinook salmon (Oncorhynchus tshawytscha): effects of inbreeding and major histocompatibility complex genotypes." Canadian Journal of Fisheries and Aquatic Sciences 59(6): 966-975.

This first major infectivity trial is carried out to examine differential genetic resistance in fish for pathogens. Captive-bred, endangered winter-run chinook salmon (Oncorhynchus tshawytscha) are used to determine resistance to three pathogens: the bacterium, Listonella (Vibrio) anguillarum, infectious hematopoietic necrosis virus (IHNV), and Myxobolus cerebralis, the parasite that causes whirling disease. Resistance to these three pathogens were compared between inbred and outbred salmon and between siblings that were heterozygous or homozygous for a class 2 gene in the major histocompatibility complex (MHC). In two of five different comparisons, significant genetic effects on disease resistance were found. First, MHC heterozygotes had a higher survival than MHC homozygotes when exposed to IHNV and the selection disadvantage of homozygotes was estimated to 8.5%. Second, outbred fish had a higher resistance than inbred fish when exposed to M. cerebralis. Using a quantitative genetics approach, it appears that there are slightly more than three gene equivalents segregating that would result in no resistance to M. cerebralis when homozygous. Overall, the investigation suggests that pathogen susceptibility in the winter-run chinook salmon will increase if further genetic variation is lost in this endangered species.

Arkush, K. D. and P. A. Siri (2001). Exploring the role of captive broodstock programs in salmon restoration. Contributions to the Biology of Central Valley Salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 319-330.

Armor, C., and P.L. Herrgesell (1985). "Distribution and abundance of fishes in the

San Francisco Bay Estuary between 1980 and 1982." Hydrobiologia 129: 211-227.
In 1980 a long-term study of the fishery resources of the San Francisco Bay estuary was initiated in an effort to delineate the importance of freshwater inflow to fish and invertebrate abundance and distribution in the bay. An analysis of the trawl data collected between January 1980 and December 1982 illustrates the influence of the timing and magnitude of freshwater inflows on fish fistribution and abundance in this estuary from the perspective of monthly, seasonal and annual time scales. Normally found in the delta, Suisun Bay and San Pablo Bay during periods of increased salinity, pelagic species moved downstream after the two peak flows studied, while demersal species usually found in Central San Francisco Bay moved upstream. Such upstream movements may be due in part to transport by strong density-driven currents. Timing and magnitude of monthly catches of some species varied on a seasonal cycle coincident with variations of freshwater inflow. Most species, especially the marine species, showed no consistent cycle of monthly catches. In the wet years of 1980 and 1982 the distributions of freshwater, estuarine and anadromous species were extended downstream into San Pablo, Central and South San Francisco Bays and some marine species, including the flatfish, were more abundant in the upstream areas. In the dry year of 1981 when bay salinities were higher, few marine species extended their distributions upstream into San Pablo and Suisun Bays. Jacksmelt was the only fish of the 15 most abundant species with its peak abundance in 1981. Most marine species were more abundant in the San Francisco Bay estuary in the wet years.

Arnold, J. D. and H. S. Yue (1997). "Prevalence, relative abundance, and mean intensity of plerocercoids of Proteocephalus sp. in young striped bass in the Sacramento-San Joaquin Estuary." California Fish and Game 83(3): 105-117.
Up to 79% of larval and juvenile striped bass, Morone saxatilis, in the Sacramento-San Joaquin Estuary harbor plerocercoids tentatively identified as Proteocephalus sp. Histological slides of infected striped bass revealed cysts encapsulating plerocercoids but no other host reaction. Prevalence of plerocercoids varied significantly among years and increased with striped bass length. Two copepods, Sinocalanus doerri and Eurytemora affinis, eaten by striped bass harbor a procercoid and are probable vectors. However, copepod abundance in the estuary and in the diet of striped bass was not consistently correlated with prevalence of plerocercoids in striped bass. Plerocercoid prevalence correlated significantly with water temperature and transparency but not with river outflow or electrical conductivity.

Arthur, J. F., and M. Ball. (1979). Factors influencing the entrapment of suspended material in the San Francisco Bay-Delta Estuary. San Francisco Bay: The urbanized estuary. T. Conomos. San Francisco, CA, Pacific Division American Association for the Advancement of Science: 143-174.
Inorganic suspended particulate matter, turbidity, particulate nutrients, phytoplankton, Neomysis mercedis (Holmes), certain other zooplankton, and juvenile striped bass (young-of-the-year) accumulate in an entrapment zone located in the upper San Francisco Bay-Delta estuary (Sacramento-San Joaquin River System). The location of this entrapment zone is regulated by the magnitude and the pattern of river inflow, as well as the tidal excursion. At Delta outflow indices of 20 m 3·s-1, the zone was located 40-45 km upstream of its location at 1,800 m3·s-1; tidal movement of the zone is from 3 to 10 km, depending on tidal phase and height. The location of the zone is related to, and can be approximated from, specific conductance values of 2 to 10 millimho·cm-1 (1-6 ‰ salinity). The concentration of constituents in the zone varied directly with Delta outflow, water depth, and tidal velocity. Depending on the constituent and environmental conditions at the time of measurement, the suspended-material concentration varied from as little as twice to as much as several hundred times the upstream or downstream concentration. The most significant environmental aspect of the entrapment zone may be that the quantity of phytoplankton and certain other estuarine biota appear to be enhanced when the zone is located in upper Suisun Bay.

Arthur, J. F. (1990). Continuous monitoring of striped bass eggs and larvae in the San Francisco Bay-Delta Estuary: a potential management tool. Sacramento, CA, U.S.

Bureau of Reclamation Report.

Arthur, J. F., M.D. Ball, and S.Y. Baughman (1996). Summary of federal and state water project environmental impacts in the San Francisco Bay-Delta Estuary, California. San Francisco Bay: The urbanized estuary. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science: 445-495.

Arthur, J. F. and M. D. Ball (1979). Factors influencing the low phytoplankton standing crop in Suisun Bay during the 1976-77 drought. Sacramento CA, U.S. Department of the Interior, Bureau of Reclamation, Technical Report.

Arthur, J. F. and M. D. Ball (1980). The significance of the entrapment zone location to the phytoplankton standing crop in the San Francisco Bay-Delta Estuary. Sacramento CA, U.S. Department of the Interior, Water and Power Resources Service, Technical Report.

A study conducted during the summer of 1978 in the upper San Francisco Bay-Delta Estuary of California further supports the theory that phytoplankton standing crops are highest when the entrapment zone is adjacent to the expansive shallows of Suisun Bay. The photic zone in the shallows of Suisun Bay constitutes a greater percentage of the total depth than in the channels. Results indicate that the phytoplankton standing crop in Suisun Bay can be regulated, within water availability limits, by manipulating delta outflow to optimize the entrapment zone location.

Arthur, J. F., M. D. Ball, et al. (1996). Summary of federal and state water project environmental impacts in the San Francisco Bay-Delta Estuary, California. San Francisco Bay: The Ecosystem. J. T. Hollibaugh. San Francisco, AAAS: 445-495.

Atwater, B. F. (1979). Ancient processes at the site of southern San Francico Bay: movement of the crust and changes in sea level. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, AAAS: 31-45.

Atwater, B. F., S. G. Conard, et al. (1979). History, landforms, and vegetation of the estuary's tidal marshes. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 347-385.

Around 8,000 to 10,000 years ago, sharply rising sea levels nursed a newborn San Francisco Bay estuary whose tidal marshes probably covered less area than open water. Thereafter the rate of submergence decreased about 10-fold, and by 6,000 years ago sediment began to maintain marshes that later spread across marginal parts San Francisco Bay. By thus counteracting or overtaking submergence, sedimentation created marshes that, as of 1850, covered about 2200 km2, nearly twice as much area as the bays. People have leveed or filled all but approximately 85 km2 of these marshes during the past 125 years. Concurrently, human activities have caused the delivery of enormous quantities of sediment to the bays and the slackening of tidal currents in sloughs, thereby contributing to the creation of nearly 75 km2 of marsh, about half of which remains pristine. Plains situated near high-tide levels are the most extensive landforms of both historic and modern marshes. Tides rather than upland tributaries created most sloughs around the bays, but riverine floods erected natural levees that confined tidal water in the Delta. Tidal marshes around San Francisco Bay typically contain13 or 14 species of vascular plants characteristic of salt marshes and are dominated by common pickleweed (Salicornia pacifica) and California cordgrass

(Spartinafoliosa). In the Delta, tidal marshes support about 40 species characteristic of fresh-water marshes and are dominated by tules and bulrushes (Scirpus spp.), cat-tails (Typha spp.), and common reed (Phragraites communis). These contrasting communities overlap around San Pablo Bay, Carquinez Strait, and Suisun Bay. Damage to tules and bulrushes during the drought of 1976-1977 confirms that intolerance of salt causes these plants to disappear toward San Francisco Bay. The disappearance of California cordgrass and common pickleweed toward the Delta, alternatively, may result from unsuccessful competition against tules, bulrushes, and other species. If export equals one quarter of net above-ground productivity, then vascular plants of the tidal marshes collectively contribute about 10 billion grams of carbon per year to other parts of the estuary.

Austin, C. (2010). Conceptual model of mercury in Tomales Bay. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
This second presentation on mercury in Tomales Bay focuses on hydrodynamics, mercury in sediment, and provides a conceptual model to support a Total Maximum Daily Load (TMDL) for mercury in Tomales Bay. (Kat Ridolfi’s first presentation focuses on methylmercury bioaccumulation in wildife prey.) Tomales Bay is a potential case study for how mine remediation may benefit the Bay-Delta. Mercury, methylation, and bioaccumulation are issues common to both Bay-Delta and Tomales Bay. They share sources in common (mercury mining and atmospheric deposition), although there are no industrial or wastewater discharges to Tomales Bay. In contrast to the Bay-Delta, mercury mining in Tomales Bay occurred recently (in the 1960s) and the single mine site was remediated in 2000. Hydrodynamic forces in Tomales Bay confine mine pollution to a localized area (Walker Creek delta) where it is buried by cleaner sediments. Our preliminary conceptual model describes that mercury in sediments is methylated and bioaccumulated through the food web to levels that sometimes exceed safe thresholds for humans and wildlife. Mean mercury in preferred shell- & sportfish is 0.2 mg/kg (the proposed target), but in less frequently consumed sportfish (sharks & rays) is 0.8 mg/kg. There are bay-wide fish consumption advisories for sport fish (but not commercial shellfish). Total mercury concentrations in sediment decrease with distance from the Walker Creek delta, as do methylmercury concentrations in benthic biota (limited data). Initially, we plan to leverage existing mercury control programs. We estimate that mine site remediation reduced loads by 90 percent (see related poster). Previously eroded mine wastes still caught in the downstream channel will be addressed by other, existing TMDLs. Marin County already has programs in place to reduce mercury from stormwater runoff. We plan to monitor mercury concentration trends in biota over time to ensure they decline to safe levels.

Austin, C., A. Myers, D.C. Whyte, and J.W. Kirchner (2010). Quantifying the effectiveness of remediation at Gambonini mercury mine in California Coast Range. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
How effective is site cleanup? Simple before-and-after comparisons of contaminant concentrations or loads can be misleading measures of remediation effectiveness, due to factors external to the remediation, including weather. We present a new analytical method, before-and-after contaminant rating curves, to correct for variations in external driving forces, and thus to clarify remediation effectiveness. We demonstrate our method using monitoring data from the Gambonini mercury mine in the California Coast Range. Measured mercury loads in a stream draining the mine site were a factor of ~1000 lower five years after remediation, compared to measurements made prior to remediation. However, the post-remediation year also had much lower rainfall, and thus would be expected to give lower mercury loads because most of the mercury comes from erosion of the waste pile. Our

calculations show that the variation in rainfall would account for a factor of ~60-80 decrease in mercury loads (98-99% removal efficiency), even without remediation. Our results also show, that (a) concentrations of mercury in sediment went down (less mine waste in stream sediment), (b) concentrations of sediment at a given stream flow went down (less sediment mobilized due to greater slope stability), and therefore (c) for a given stream flow, a much smaller load of mercury left the site. Therefore, the mine remediation can be shown to have reduced mercury loads by a factor of 10-20 (90-95%) on an all-else-equal basis.

Ayres, D. R., D. Garcia-Rossi, et al. (1999). "Extent and degree of hybridization between exotic (Spartina alterniflora) and native (S. foliosa) cordgrass (Poaceae) in California, USA determined by random amplified polymorphic DNA (RAPDs)." Molecular Ecology 8: 1179-1186.

The purpose of this study was to determine the spread of smooth cordgrass (Spartina alterniflora) and Spartina foliosa x alterniflora hybrids within the San Francisco Bay and along the California coast, and to examine the degree of hybridization occurring in the marshes using species-specific nuclear DNA markers. The authors consider -- (1) where do hybrid populations occur?; (2) how extensive is the hybridization in areas of overlap?; and (3) what are the frequencies of the various hybrid classes, and does this suggest that introgressive hybridization is taking place? They also consider the ecosystem impacts of the proliferation of the hybrid and S. alterniflora, and suggest strategies for their control in California.

Baerwald, M., V. Bien, F. Feyrer, and B. May (2007). "Genetic analysis reveals two distinct Sacramento splittail (Pogonichthys macrolepidotus) populations " Conservation Genetics 8(1): 159-167.

The Sacramento splittail is an endemic cyprinid fish of the San Francisco estuary and its tributaries, which is a highly manipulated, constantly changing ecosystem. Splittail is the only extant member of its genus and is listed as a federal and California Species of Special Concern due to uncertainties regarding long-term abundance trends. Determining population structure for splittail is important because unique populations may contain different adaptive genetic variation, which can allow one population to persist through future environmental or demographic stochasticity while others become extirpated. To assess splittail population structure, 13 microsatellite markers were used to genotype 489 young-of-year splittail from five major rivers draining into the estuary: Cosumnes, Napa, Petaluma, Sacramento, and San Joaquin Rivers. Two genetically distinct populations were found to exist within our study region; one largely comprised of splittail collected from the Petaluma and Napa Rivers and the second comprised of splittail collected from tributaries in California's Central Valley: Cosumnes, Sacramento, and San Joaquin Rivers. These results were replicated in two consecutive years with both distance and model-based algorithms. The genetic distinction between these two populations appears correlated with salinity differences between migratory regions and spawning grounds. Splittail from the Petaluma River exhibited a significantly higher degree of differentiation from the Central Valley population than did Napa River splittail. Our results suggest on-going monitoring programs are probably highly biased towards sampling splittail from the Central Valley population. Understanding population dynamics of splittail could be improved if monitoring programs were expanded to include all splittail populations.

Baerwald, M., V. Bien, et al. (2006). "Microsatellite analysis reveals two genetically distinct splittail (Pogonichthys macrolepidotus) populations in the San Francisco Estuary." Conservation Genetics.

Baerwald, M. R., , B.M. Schreier, G.Schumer & B. May (2012). "Detection of Threatened Delta Smelt in the Gut Contents of the Invasive Mississippi Silverside in the San Francisco Estuary Using TaqMan Assays." Transactions of the American Fisheries Society 141(6): 8.

- Genetic analyses of gut contents to detect predation is both sensitive and accurate when analyzing wild caught predators.
- Mississippi silversides prey upon larval delta smelt in the Sac deepwater ship channel, though detections were restricted to fish from the center of the channel (collected by Kodiak trawl).

-        Captive feeding trial results indicate that smelt DNA remains at detectable levels for 12-36 hours post-ingestion. Traditional visual analysis is only capable of detecting predation 30-60 minutes post-ingestion.

Baerwald, M. R. and B. May (2004). "Characterization of microsatellite loci for five members of the minnow family Cyprinidae found in the Sacramento-San Joaquin Delta and its tributaries." Molecular Ecology Notes 4(3): 385-390.
        Two microsatellite-enriched libraries [(CAGA) sub(n), (TAGA) sub(n)] were constructed using pooled DNA from three cyprinid species native to the Sacramento-San Joaquin Delta of California: Sacramento splittail (Pogonichthys macrolepidotus); Sacramento pikeminnow (Ptychocheilus grandis); and tui chub (Siphateles bicolor). Primers were designed for 105 loci and tested for levels of polymorphism in five cyprinid species found in the Delta: Sacramento splittail, Sacramento pikeminnow, tui chub, hitch (Lavinia exilicauda), and Sacramento blackfish (Orthodon microlepidotus). Fifty-one loci were polymorphic for at least one species and 31 loci were polymorphic for multiple species. The number of polymorphic loci per species ranged from 16 to 26.

Bailey, H. C., C. Alexander, C. DiGiorgio, M. Miller, S. Doroshov and D. Hinton. (1994). "The effect of agricultural discharge on striped bass in California's Sacramento-San Joaquin drainage." Ecotoxicology 3(2): 123-142.
        The striped bass (Morone saxatilis) population of the Sacramento-San Joaquin Delta has declined approximately 80% since the mid-1970s. This decline has been attributed to factors such as water diversions, pollution and reduced abundance of food organisms. One source of potential pollutants is agricultural return water. The Colusa Basin Drain discharges water from over 150,000 acres and can account for over 20% of the flow of the Sacramento River. Because discharge occurs at the same time striped bass are spawning, early developmental stages could be adversely affected. Toxicity studies conducted over a 3 year period consistently demonstrated acute toxicity to striped bass larvae and to opossum shrimp (Neomysis mercedis), an important food organism for juvenile striped bass. Acute toxicity was also demonstrated with striped bass embryos. In addition, a model based on pesticide use more effectively predicted striped bass recruitment during the period of decline than did a model based on historically important river flows and delta diversions. These studies indicate that agricultural return water should not be disregarded when considering potential causes of the decline of striped bass.

Bailey, H. C., L. Deanovic, et al. (2000). "Diazinon and chlorpyrifos in urban waterways in northern California, USA." Environmental Toxicology and Chemistry 19(1): 82-87.
        Samples collected from urban streams in the cities of Sacramento and Stockton, California, USA, during the precipitation season were analyzed for diazinon and chlorpyrifos. Concentrations were determined with enzyme-linked immunosorbent assays specific for each pesticide. Two hundred thirty-one samples from the two cities were analyzed for diazinon; 85% exceeded California Department of Fish and Game water-quality criteria for this pesticide. Chlorpyrifos was measured in 90 of the samples collected from Sacramento and Stockton; 80% exceeded the California Department of Fish and Game criterion for this pesticide. Thirty-six of 47 samples (76.6%) tested for toxicity produced total mortality within 72 h with Ceriodaphnia dubia. Toxicity identification evaluations on selected samples confirmed that toxicity was primarily due to one or both of these pesticides. Uses of diazinon and chlorpyrifos in urban areas include dormant sprays on fruit trees, professional landscape and maintenance uses, and structural pest control. Pesticide concentrations were lower in a catchment favoring commercial and industrial activities compared with a catchment receiving largely residential inputs. Aerial drift from agricultural applications may play a role in storm-water concentrations.

Baines, S. B., N. S. Fisher, et al. (2004). "Light dependence of selenium uptake by phytoplankton and implications for predicting selenium incorporation into food webs." Limnology and Oceanography 49(2): 566-578.
        The potentially toxic element selenium is first concentrated from solution to a large but highly variable degree by algae and bacteria before being passed on to consumers. The large loads of abiotic and detrital suspended particles often

present in rivers and estuaries may obscure spatial and temporal patterns in Se concentrations at the base of the food web. We used radiotracers to estimate uptake of both selenite (Se(IV)) and C by intact plankton communities at two sites in the Sacramento/San Joaquin River Delta. Our goals were to determine (1) whether C and Se(IV) uptake were coupled, (2) the role of bacteria in Se(IV) uptake, and (3) the Se:C uptake ratio of newly produced organic material. Se(IV) uptake, like C uptake, was strongly related to irradiance. The shapes of both relationships were very similar except that at least 42-56% of Se(IV) uptake occurred in the dark, whereas C uptake in the dark was negligible. Of this dark Se(IV) uptake, 34-67% occurred in the 0.2-1.0- mu m size fraction, indicating significant uptake by bacteria. In addition to dark uptake, total Se(IV) uptake consisted of a light-driven component that was in fixed proportion to C uptake. Our estimates of daily areal Se(IV):C uptake ratios agreed very well with particulate Se:C measured at a site dominated by phytoplankton biomass. Estimates of bacterial Se:C were 2.4-13 times higher than for the phytoplankton, suggesting that bacteriovores may be exposed to higher dietary Se concentrations than herbivores.

Baines, S. B., N. S. Fisher, et al. (2002). "Assimilation and retention of selenium and other trace elements from crustacean food by juvenile striped bass (Morone saxatilis)." Limnology and Oceanography 47(3): 646-655.
Estimates of the assimilation and retention of trace elements from food by fish are useful for linking toxicity with the biogeochemical cycling of these elements through aquatic food webs. Here we use pulse-chase radiotracer techniques to estimate the assimilation and retention of Se and four trace metals, Ag, Am, Zn, and Cd, by 43- and 88-d-old juvenile striped bass, Morone saxatilis, from crustacean food. Brine shrimp nauplii, Artemia franciscana, or adult copepods, Acartia tonsa, were fed radiolabeled diatoms and then fed to juvenile striped bass. Assimilation efficiencies (AEs plus or minus SD) for 43-d-old fish were 18 plus or minus 2%, 6 plus or minus 1%, 23 plus or minus 4%, 33 plus or minus 3%, and 23 plus or minus 2% for Ag, Am, Cd, Se, and Zn, respectively. For 88-d-old fish, the AEs were 28 plus or minus 1%, 42 plus or minus 5%, and 40 plus or minus 5% for Cd, Se, and Zn, respectively. The higher AEs in the older fish may result from longer gut passage times for larger fish. The 44-d-old fish excreted 5 plus or minus 0.8%, 4 plus or minus 2.0%, 7 plus or minus 0.3%, 9 plus or minus 0.4%, and 1.3 plus or minus 0.9% of the Ag, Am, Cd, Se, and Zn, respectively, they ingested from food per day, whereas the 88-d-old fish excreted 3 plus or minus 1.0%, 8 plus or minus 0.5%, and 3 plus or minus 0.5% of the assimilated Cd, Se, and Zn per day, respectively. Predictions of steady state Se concentrations in juvenile striped bass tissues made using a biokinetic model and the measured AE and efflux rates ranged from 1.8 to 3.0 mu g Se g super(-1) dry wt for muscle tissue and 6.8 to 11.6 mu g Se g super(-1) dry wt for gut tissue. These predictions agreed well with average values of 2.1 and 13 mu g Se g super(-1) dry wt measured independently in North San Francisco Bay, where elevated Se concentrations are of concern. The model results imply that the planktonic food web, including juvenile striped bass, does not transfer Se as efficiently to top consumers as does the benthic food web.

Baker, P. F., and J.E. Morhardt (2001). Survival of chinook salmon smolts in the Sacramento-San Joaquin Delta and Pacific Ocean. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 163-182.
This paper summarizes current knowledge about the effects of river flow and water export on the survival of San Joaquin River Basin chinook salmon smolts migrating through the Sacramento-San Joaquin Delta. As will become clear, there are serious deficiencies in our understanding of the needs of smolts as they pass through this region, but there is a general agreement that mortality can be high and can probably be reduced by management actions. The potential for success of the various alternatives remains speculative; something needs to be done, but it remains unclear what will work best. For example, smolt survival is usually better at very high (flood) flows than at very low flows, but there is little solid information about the potential for improved survival in the range that might be managed regularly. Researchers have not really begun the search for optimal flows for smolt survival; analyses to date offer, at best, only the qualitative guidance that “higher” flows are “better” for salmon, without any indication of just how much

better survival can be or should be. Similarly, although there is reason to believe that strategically placed barriers should improve smolt survival, by keeping smolts well away from the Delta export pumps; however, experiments to date have not been able to demonstrate or refute the effectiveness of such barriers directly.

Baker, P. F., T. P. Speed, et al. (1995). "Estimating the influence of temperature on the survival of chinook salmon smolts (Oncorhynchus tshawytscha) migrating through the Sacramento-San Joaquin River delta of California." Canadian Journal of Fisheries and Aquatic Sciences 52(4): 855-863.
        Data from the U.S. Fish and Wildlife Service are used to investigate the relationship between water temperature and survival of hatchery-raised fall-run chinook salmon (Oncorhynchus tshawytscha) smolts migrating through the Sacramento - San Joaquin Delta of California. A formal statistical model is presented for the release of smolts marked with coded-wire tags (CWTs) in the lower Sacramento River and the subsequent recovery of marked smolts in midwater trawls in the delta. This model treats survival as a logistic function of water temperature, and the release and recovery of different CWT groups as independent mark-recapture experiments. Iteratively reweighted least squares is used to fit the model to the data, and simulation is used to establish confidence intervals for the fitted parameters. A 95% confidence interval for the upper incipient lethal temperature, inferred from the trawl data by this method, is 23.01 plus or minus 1.08 degree C. This is in good agreement with published experimental results obtained under controlled conditions (24.3 plus or minus 0.1 and 25.1 plus or minus 0.1 degree C for chinook salmon acclimatized to 10 and 20 degree C, respectively): this agreement has implications for the applicability of laboratory findings to natural systems.

Baldocchi, D., M. Detto, J. Verfaillie, O. Sonnentag, J. Hatal, and F. Anderson (2010). Trials and tribulations on measuring greenhouse gas (carbon dioxide, methane and water vapor) fluxes over a peatland pasture and rice paddy in the Sacramento-San Joaquin Delta. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
        New advances in laser spectrometers are enabling us to measure greenhouse gas (methane, carbon dioxide, water vapor) fluxes directly and quasi-continuously with the eddy covariance technique. We have been measuring methane, carbon dioxide and water vapor fluxes for the past 3 years over a degraded peatland pasture on Sherman Island and over a rice paddy on Twitchell Island the past year. These measurements are enabling us to deduce rates of net and gross greenhouse gas exchange that is occurring over drained and flooded peatlands in the Delta. However, to avoid potential artifacts due to advection from upwind wetlands, ditches and/or cows, we conducted a set of ancillary studies that help us interpret our flux measurements. In this talk we report on our flux measurements. In summary we find that the drained pasture is a small source of methane (< 10 nmol m-2 s-1), a moderate source of carbon dioxide and a steady source of water vapor (> 700 mm/y). The episodic occurrence of cows in the flux footprint yields methane fluxes that exceed 100 nmol m-2 s-1. In comparison, the rice paddy is a small source of methane (5-15 nmol m-2 s-1), a net sink for CO_2 from the atmosphere (about 200 gC m-2 y-1) and an strong source of water vapor (> 1000 mm/y).

Ball, M. D. (1975). Chlorophyll levels in the Sacramento-San Joaquin Delta to San Pablo Bay. Proceedings of a workshop on algae nutrient relationships in the'San Francisco Bay and Delta'. R. L. Brown. San Francisco, The San Francisco Bay and Estuarine Association.

Ball, M. D. (1987). Phytoplankton dynamics and planktonic chlorophyll trends in the San Francisco Bay-Delta Estuary. Sacramento CA|, U.S. Bureau of Reclamation; Exhibit No.103.

Ball, M. D. and J. F. Arthur (1979). Planktonic chlorophyll dynamics in the northern San Francisco bay and delta. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 265-285.
        Diatoms were the dominant phytoplankters throughout the Sacramento-San Joaquin Delta into San Pablo Bay during 1969 through 1977. Green algae seldom

exceeded 20% of the total. Chlorophyll a concentrations seldom exceeded 6 µg·liter-1 at the most upstream station in the Sacramento River, the major water source to the Delta, except during the 1977 drought when 40 µg·liter-1 was measured. Conversely, peak summer chlorophyll concentrations entering the Delta from the San Joaquin River were the highest (100-350 µg·liter-1 and were inversely related to riverflow. During spring through fall, export pumping from the southern Delta caused a net flow reversal in the lower San Joaquin River, drawing Sacramento River water across the central Delta to the export pumps. The relatively deep channels and short water residence time apparently resulted in the chlorophyll concentrations remaining low from the northern Delta and in the cross-Delta flow to the pumps. Chlorophyll concentrations in the shallower eastern Delta sloughs and channels were often quite high and variable. Western Delta spring blooms reached concentrations of 25-50 µg·liter-1. Spring blooms of 30-40 and summer blooms of 40-100 µg·liter-1 were observed in Suisun Bay. The entrapment zone location adjacent to the shallows of Suisun and Honker bays appears to increase the Suisun Bay phytoplankton standing crop. Chlorophyll a concentrations in Suisun Marsh generally peaked to 40-100 µg·liter-1 in the late spring except during 1977. Chlorophyll levels in central San Pablo Bay seldom exceeded 6 µg·liter-1, although blooms as high as 40 µg·liter-1 were observed in the northern shallow portion of the Bay. Percent chlorophyll a (of the total chlorophyll a plus the pheo-pigments) in near-surface water generally varied from 50-80% during the spring-fall months throughout most of the study area. Upstream of the entrapment zone, percent chlorophyll a near the bottom averaged about 5% lower than that near the surface. Downstream of the entrapment zone, percent chlorophyll a was as much as 40% lower near the bottom

Ball, M. D. and J. F. Arthur (1981). "Phytoplankton settling rates -- A major factor in determining estuarine dominance." Estuaries 4(3).

Settling rates of the phytoplankton dominating the entrapmemnt zone (turbidity maximum) in the upper San Francisco Bay-Delta Estuary were measured in 1980, using a special device designed to collect undisrupted samples. The data is being used to develop a numerical multilayered phytoplankton model. Results indicated the dominant species (Thalassiosira excentricus and Skeletonema costatum) settle at 1.5 to 6 m per day with average rates about equal to calculated maximum net upward vertical water velocities resulting from two layered flow circulation. Maximum settling rates are associated with medium salinities and high concentrations of suspended solids and chlorophyll.

Baltz, D. M., P.B. Moyle, and N.J. Knight (1982). "Competitive interactions between benthic stream fishes, riffle sculpin, Cottus gulosus, and speckled dace, Rhinichthys osculus." Canadian Journal of Fisheries and Aquatic Sciences 39: 1502-1511.

Two morphologically dissimilar stream fishes occupied the same microhabitat in different riffles of Deer Creek, Tehama County, California. In a 12.5 km reach of the creek, speckled dace (Rhinichthys osculus) dominated riffles at the lower end while riffle sculpin (Cottus gulosus) dominated the riffles at the upper end, where dace were confined to slower water. Between these sets of riffles, relative abundances of the two species were negatively correlated. Routine metabolic rates of sculpin increased rapidly with temperature and indicated that sculpins were unable to tolerate temperatures in the low elevation riffles in the summer. Dace swimming performance appeared to be adequate at low temperatures to permit them to occupy the sculpin-dominated riffles. However, stream tank experiments indicated that at low temperatures sculpin were able to displace dace from cover in high velocity water. Our analysis thus demonstrated that competitive interactions between dace and sculpin for preferred microhabitat were mediated by temperature.

Baltz, D. M., and P.B. Moyle (1993). "Invasion resistance to introduced species by a native assemblage of California stream fishes." Ecological Applications: a publication of the Ecological Society of America 3: 246-255.

Assemblages of native stream fishes in California show a remarkable ability to resist invasion by introduced fishes as long as the streams are relatively undisturbed by human activity. Previous studies had indicated a high degree of spatial (microhabitat) segregation among the native fishes, which was confirmed by a principal components analysis of microhabitat use data from Deer Creek, a tributary

of the Sacramento River. A null modelling study using the same data set was performed to see if competition was a major force structuring the assemblage, because theoretical studies had indicated that a competitively structured assemblage should be most able to resist invasions. The null models indicated that competition was not the major structuring force, so it is likely the assemblages are structured through a combination of morphological specialization (reflecting evolutionary history), predation, and some competition. The assemblages resist invasion through both environmental and biotic factors. Predation seems to be an especially important biotic factor.

Baltz, D. M., P. B. Moyle, et al. (1982). "Competitive interactions between benthic stream fishes, riffle sculpin, Cottus gulosus, and speckled dace, Rhinichthys osculus." Canadian Journal of Fisheries and Aquatic Sciences 39: 1502-1511.
Two morphologically dissimilar stream fishes occupied the same microhabitat in different riffles of Deer Creek, Tehama County, California. In a 12.5 km reach of the creek, speckled dace (R. osculus) dominated riffles at the lower end while riffle sculpin (C. gulosus) dominated the riffles at the upper end, where dace were confined to slower water. Between these sets of riffles, relative abundances of the two species were negatively correlated. Routine metabolic rates of sculpin increased rapidly with temperature and indicated that sculpins were unable to tolerate temperatures in the low elevation riffles in the summer. Dace swimming performance appeared to be adequate at low temperatures to permit them to occupy the sculpin-dominated riffles. However, stream tank experiments indicated that at low temperatures, sculpin were able to displace dace from cover in high velocity water. The authors analysis thus demonstrated that competitive interactions between dace and sculpin for preferred microhabitat were mediated by temperature.

Banks, H. T., L. W. Botsford, et al. (1989). Estimation of growth and survival in size-structured cohort data: an application to larval striped bass (Morone saxatilis). Davis, CA, Center for Applied Mathematics Technical Report; #89-10.

Banks, M., and D.P. Jacobson (2010). Progress in molecular discrimination among California’s chinook salmon runs: contrasting microsatellites, clock-genes and SNPs. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The application of DNA based markers towards the task of discriminating among California’s Central Valley runs has evolved in accord with ongoing genomic developments. A host of innovations in this field has increasingly enabled us to resolve which genetic markers associate with important life history differences among runs. Accuracy for identification of most likely source population encountered at salvage or water monitoring facilities has far reaching consequences for improving measures for Chinook management, restoration and conservation. We thus continue to focus on developing new tools to provide the greatest statistical power for run identification. In accord, improved methods for identification of threatened or endangered stocks at sites where they might be at risk for loss allows water policy measures to affect most prompt response to changes in encounter rates. As a proof of concept for these claims, we conducted a blind test of over 500 known origin Chinook to compare and contrast the ability of different molecular markers (including microsatellites, clock-genes and single nucleotide polymorphisms (SNPs)) to correctly resolve the identity of these test samples. Pleasingly, we demonstrate that overall power continues to increase, while cost to run genetic assays has decreased.

Banks, M. A., B.A. Baldwin, and D. Hedgecock (1996). "Research on chinook salmon (Oncorhynchus tshawytscha) stock structure using microsatellite DNA." Bulletin of National Research Institute of Aquaculture Supplement 2: 5-9.

Banks, M. A., M.S. Blouin, B.A. Baldwin, V.K. Rashbrook, H.A. Fitzgerald, S.M. Blankenship, and D. Hedgecock (1999). "Isolation and inheritance of novel microsatellites in chinook salmon (Oncorhynchus tshawytscha)." The Journal of Heredity 90(2): 281-288.
We describe the isolation, PCR amplification, and characterization of 10 new microsatellite loci (Ots-1-Ots-10) for the federally protected chinook salmon

(Oncorhynchus tschawytscha). We investigate the inheritance and linkage of these loci as well as a previously published locus, Oneµ13, in families obtained from artificial crosses. Mendelian transmission is confirmed for 76 of 80 segregations observed. Of the four deviations, two appear to have resulted from gametic segregation distortion. The other two provide evidence for the existence of at least one null allele. We also identify 'drop out' of large alleles in these two families owing to competitive PCR amplification of smaller alleles. There is no evidence for linkage between any pair of loci. One mutation observed at Ots-2 is reported and confirmed by DNA sequencing. We estimate the mutation rate of this locus to be 6.5 x 10-4 (95%) confidence interval 3.6 x 10-3 to 1.6 x 10-4, respectively). Characterizing a mutant allele at Ots-2 offers the first step toward understanding mutation rates for chinook microsatellites. Owing to their Mendelian inheritance, these new loci provide reliable markers for high-resolution population genetics studies of this species.

Banks, M. A., and W. Eichert (2000). "WHICHRUN (Version 3.2): a computer program for population assignment of individuals based on multilocus genotype data." Journal of Heredity 91(1): 87-89.

Banks, M. A., M. S. Blouin, et al. (1999). "Isolation and Inheritance of Novel Microsatellites in Chinook Salmon (Oncorhynchus tschawytscha)." Journal of Heredity 90(2): 281-288.

We describe the isolation, PCR amplification, and characterization of 10 new microsatellite loci (Ots-1-Ots-10) for the federally protected chinook salmon (Oncorhynchus tschawytscha). We investigate the inheritance and linkage of these loci as well as a previously published locus, One mu 13, in families obtained from artificial crosses. Mendelian transmission is confirmed for 76 of 80 segregations observed. Of the four deviations, two appear to have resulted from gametic segregation distortion. The other two provide evidence for the existence of at least one null allele. We also identify "drop out" of large alleles in these two families owing to competitive PCR amplification of smaller alleles. There is no evidence for linkage between any pair of loci. One mutation observed at Ots-2 is reported and confirmed by DNA sequencing. We estimate the mutation rate at this locus to be 6.5 x 10 super(-4) (95% confidence interval 3.6 x 10 super(-3) to 1.6 x 10 super(-4), respectively). Characterizing a mutant allele at Ots-2 offers the first step toward understanding mutation rates for chinook microsatellites. Owing to their Mendelian inheritance, these new loci provide reliable markers for high-resolution population genetics studies of this species.

Banks, M. A., V. K. Rashbrook, et al. (2000). "Analysis of microsatellite DNA resolves genetic structure and diversity of chinook salmon (Oncorhychus tshawytscha) in California's Central Valley." Canadian Journal of Fisheries and Aquatic Sciences 5: 915-927.

10 microsatellite DNA markers were used to assess genetic diversity within and among the four runs (winter, spring, fall, and late fall) of chinook salmon (Oncorynchus tshawytscha) in California's Central Valley. Forty-one population samples are studied, comprising naturally spawning and hatchery stocks collected from 1991 through 1997. Maximum likelihood methods are used to correct for kinship in juvenile samples and run admixture in adult samples. Through simulation, the relationship between sample size and number of alleles observed at polymorphic microsatellite markers is determined. Most samples have random-mating equilibrium proportions of single and multilocus genotypes. Temporal and spatial genetic heterogeneity is minimal among samples within subpopulations. An F sub(ST) of 0.082 among subpopulations, however, indicates substantial divergence among runs. Thus, with the exception of this discovery of two distinct lineages of spring run, genetic structure accords with the diverse chinook life histories seen in the Central Valley and provides a means for discrimination of protected populations.

Barnard, P. (2010). Anthropogenic influences on recent bathymetric change in west-central San Francisco Bay and implications for beach sustainability. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

From 1997 to 2008, west-central San Francisco Bay lost over 14 million cubic meters of sediment, the majority of which was located within aggregate mining lease sites. The rate of sediment loss is nearly three times the rate determined from bathymetric surveys spanning 1947 to 1979, indicating a rapid acceleration of sediment loss from the region during the last decade. As only 10% of the mapped substrate is dominated by mud, and only 5% of the measured sediment loss is from mud-dominated substrates, the majority of the sediment lost from west-central San Francisco Bay was coarse sediment, material that would otherwise have been available for transport to eroding, open-coast beaches. While it is difficult to establish the precise contribution of the various potential anthropogenic influences to the observed sediment loss from 1997 to 2008 in west-central San Francisco Bay, the timing, spatial distribution, and magnitude of sediment loss suggests a strong correlation with sediment removal by aggregate mining activities. Sediment loss in the entire San Francisco Bay Coastal System during the last half-century is estimated at 240 million cubic meters, and most of this is believed to be coarse sediment (i.e., sand and gravel) from Central Bay and the San Francisco Bar, which is likely to limit the sand supply to adjacent, open-coast beaches. This hypothesis is supported by a calibrated numerical model that indicates that there is a potential net export of sand-sized sediment across the Golden Gate, suggesting that a reduction in the supply of sand-sized sediment within west-central San Francisco Bay will limit transport to the outer coast. The massive loss of sediment from the system, as a whole, is due to a combination of factors that include delta management practices, in-bay dredging, and aggregate mining.

Barnard, P. L., D. M. Hanes, et al. (2006). "Giant sand waves at the mouth of San Francisco Bay." EOS 87(29).

Barnett, R., and others (2008). Water quality conditions in the Sacramento-San Joaquin Delta and Suisun and San Pablo Bays during 2006. Water Quality Conditions in the Sacramento-San Joaquin Delta and Suisun and San Pablo Bays. Sacramento, California Department of Water Resources: 169 pp.

Barnett-Johnson, R., P. Weber, J.D. Wikert, T. Heyne, E. Vasquez, G. Whitman, and C. Sinclair (2010). Do salmon hatchery ‘sources’ lead to in-river ‘sinks’ in conservation?: Implications for integrated hatchery management in California 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Maintaining viable populations of salmon in the wild is a primary goal for many recovery programs. The frequency and extent of connectivity among natal sources defines the demographic and genetic boundaries of a population. Yet the role that immigration of hatchery fish may play in altering population dynamics and fitness of natural populations remains largely unquantified. Quantifying whether natural populations are self-replenishing, function as sources (births > mortality; r > 1), or potentially sinks (births < mortality; r < 1) is often limited by an inability to determine how immigration and emigration influence population processes. In this study we demonstrate that the natural spawning population of Chinook salmon (Oncorhynchus tshawytscha) on the Mokelumne River, California (USA) represents a sink population. We retrieved sulfur isotopes (34S/32S) in adult Chinook salmon otoliths (ear bones) using an ion microprobe that were deposited during their early life history as juveniles to determine whether individuals were produced in hatcheries or in the wild. Our results show that only 10% ± (6-20%; 95% confidence interval (CI)) of adults spawning in the wild had otolith δ34S values less than 8.5‰ characteristic of naturally produced salmon. On a watershed level, 97% ± (88-98% CI) of returning adults were determined to be of hatchery-origin. Results from our cohort reconstruction indicate that the significant number of hatchery immigrants contributes to the appearance of positive population growth in 9 of 12 years. However, the in-river population would have declined (r=0.25) in the absence of immigration from hatchery sources in all years (1992-2004). The results of this study are compared to Integrated Hatchery Management criteria to evaluate the natural population fitness handicap due to the influence of hatchery spawners. These findings highlight the potential dangers in ignoring source-sink dynamics in recovering natural populations, and question the extent to which natural salmon are becoming replaced with hatchery fish.

Barnum, D. A. and N. H. J. Euliss (1991). "Impacts of changing irrigation practices on waterfowl habitat use in the southern San Joaquin Valley, California, USA." California Fish and Game 77(1): 10-21.

The authors used diurnal aerial census data to examine habitat use patterns of ducks wintering in the southern San Joaquin Valley, California from 1980-87. They calculated densities (birds/ha) for the northern pintail (Anas acuta), mallard (A. platyrhynchos), green-winged teal (A. crecca), cinnamon teal (A. cyanoptera), shoveler (A. clypeata), ruddy duck (Oxyura jamaicensis), and total ducks in each of 5 habitats. Densities of pintail and total ducks were greater in September than in other months. From October through January, density of teal and total ducks was greatest on Kern National Wildlife Refuge (NWR). Densities of ruddy duck and pintail were greatest on agricultural drainwater evaporation ponds and preirrigated cropland, respectively.

Barrick, D., R. Cheng, et al. (2000). Toward bay/harbor circulation model improvement incorporating HF radar data based on SeaSonde deployments on San Francisco Bay. Where Marine Science and Technology Meet Oceans 2000 CD-ROM. Washington, D.C., Marine Technology Society.

Two High-Resolution SeaSonde HF radars were deployed on San Francisco Bay during Summer 1999. Normal total vector map coverage was produced in the common overlap area East of Tiburon, North of Golden Gate. We focus here on the important Golden-Gate region with the highest flows, which was seen only by the radar on Treasure Island. This is a case where perhaps single-site radial coverage is adequate. The radar surface currents in this region are compared with the U.S.G.S. TRIM2D vertically integrated circulation model outputs for the bay. The tidal harmonic amplitudes compare favorably except at one location directly beneath Golden Gate Bridge where flow through the mouth is the most constricted.

Barron, T. (1998). "Reducing metal discharges to south San Francisco Bay." Environmental Regulation and Permitting 7(4): 67-79.

Copper in urban runoff and POTW discharges poses a problem for aquatic life in South San Francisco Bay. Local business, government agencies, and citizen's groups have worked together since the early 1990s to discover cost-effective ways of reducing copper in wastewaters that come from industrial, residential, and other sources. This article describes how three South Bay POTWs successfully incorporated specific pollution prevention measures into their wastewater discharge ordinances to significantly decrease the amount of waste copper coming from industrial sources.

Bartholow, J., R. B. Hanna, et al. (2001). "Simulated Limnological Effects of the Shasta Lake Temperature Control Device." Environmental Management 27(4): 609-626.

We estimated the effects of a temperature control device (TCD) on a suite of thermodynamic and limnological attributes for a large storage reservoir, Shasta Lake, in northern California. Shasta Dam was constructed in 1945 with a fixed-elevation penstock. The TCD was installed in 1997 to improve downstream temperatures for endangered salmonids by releasing epilimnetic waters in the winter/spring and hypolimnetic waters in the summer/fall. We calibrated a two-dimensional hydrodynamic reservoir water quality model, CE-QUAL-W2, and applied a structured design-of-experiment simulation procedure to predict the principal limnological effects of the TCD under a variety of environmental scenarios. Calibration goodness-of-fit ranged from good to poor depending on the constituent simulated, with an R2 of 0.9 for water temperature but 0.3 for phytoplankton. Although the chemical and thermal characteristics of the discharge changed markedly, the reservoir's characteristics remained relatively unchanged. Simulations showed the TCD causing an earlier onset and shorter duration of summer stratification, but no dramatic affect on Shasta's nutrient composition. Peak in-reservoir phytoplankton production may begin earlier and be stronger in the fall with the TCD, while outfall phytoplankton concentrations may be much greater in the spring. Many model predictions differed from our a priori expectations that had been shaped by an intensive, but limited-duration, data collection effort. Hydrologic and meteorological variables, most notably reservoir carryover storage at the beginning of the calendar year, influenced model predictions much more strongly than the TCD. Model results indicate that greater control over reservoir limnology and release quality may be gained by carefully managing reservoir volume through the year than with the TCD alone.

Bartholow, J. M. (2004). "Modeling Chinook Salmon with SALMOD on the Sacramento River, California." Hydroecologie appliquee 14(1): 193-219.
Four races of Pacific salmon crowd the Sacramento River below a large reservoir that prevents access to historical spawning grounds. Each race is keyed to spawn at specific times through the year. A salmon population model was used to estimate: (1) the effects that unique run timing, interacting with seasonal river flows and water temperatures, have on each race; and (2) which habitats appeared to be the most limiting for each race. The model appeared to perform well without substantive calibration. Late fall, winter, and spring run Chinook do not appear to have the same production potential as fall run Chinook even though fall run production is more variable than that for the other three races. Spring fish have the lowest production on average, and production appears to be declining through time, perhaps making that race harder to recover should the population become more depressed. Rearing habitat appears to be the factor most limiting production for ail races, but water temperature is responsible for most year-to-year production variation.

Baskerville-Bridges, B., J. C. Lindberg, et al. (2004). The Effect of Light Intensity, Alga Concentration, and Prey Density on the Feeding Behavior of Delta Smelt Larvae. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 219-227.
Understanding how environmental factors influence first feeding success is critical for the conservation-oriented larval culture of delta smelt Hypomesus transpacificus, a threatened osmerid endemic to the San Francisco Estuary. We investigated the effects of light intensity, alga concentration, and prey (rotifer) density on feeding of cultured delta smelt larvae. In one experiment, first feeding larvae were exposed to three light intensities (0.01, 0.3, and 1.9 mu moles times s super(-1) times m super(-2)) and three alga concentrations (0, 0.5, and 2 x 10 super(6) cells/mL). Intestinal contents were examined to determine the incidence of feeding and gut fillness. Maximum feeding responses (92% feeding; 4.8 rotifers/feeding larva in 2 h) were observed at the highest light intensity and alga concentrations; feeding sharply declined with a reduction of either factor. A second experiment was performed to study the effect of alga concentration (0, 1.5, 3, and 6 x 10 super(6) cells/mL) in more detail. Feeding responses were very low without algae (13% feeding; 2.1 rotifers/feeding larva in 2 h), but dramatically increased at high concentrations (83% feeding; 5.1 rotifers/feeding larvae in 2 h). In a third experiment, the effect of prey (rotifer) density (0.1, 1, 10, and 100 rotifers/mL) was tested, which significantly enhanced feeding up to the 10/mL treatment (84% feeding; 4.2 rotifers/feeding larvae in 1 h). All three environmental factors significantly affected feeding success of larval delta smelt. Optimization of these factors has improved survival and growth during the sensitive larval period and has improved laboratory culture of delta smelt.

Batzer, D. P., M. McGee, V.H. Resh, and R.R. Smith (1993). "Characteristics of invertebrates consumed by mallards and prey response to wetland flooding schedules." Wetlands 13(1): 41-49.
We examined characteristics of the invertebrates consumed by mallards (Anas platyrhynchos) and green-winged teals (Anas crecca) and responses of these invertebrates to manipulations of flooding date in Suisun Marsh, Solano County, CA. Numbers of Chironomus stigmaterus midge larvae (Chironomidae) and Eogammarus confervicolus amphipods (Gammaridae) in mallard esophageal samples were positively correlated with abundance of these invertebrates in wetlands. Mallards primarily consumed large midge larvae (fourth instars) and amphipods (>5 mm in length). Smaller green-winged teals consumed smaller midges. Mallards consumed few Trichocorixa verticalis water boatmen (Corixidae) or Cricotopus sylvestris midge larvae, despite their being abundant. Wetlands first flooded in early September had higher winter populations of amphipods and Berosus ingeminatus beetle larvae (Hydrophilidae) than wetlands first flooded in late October. Late-winter abundance of benthic C. stigmaterus midge larvae was highest at 40-cm water depths in the former habitats and at 20-cm depths in the latter habitats.

Batzer, D. P., F. De Szalay, and V.H. Resh (1997). "Opportunistic response of a benthic midge (Diptera: Chironomidae) to management of California seasonal wetlands." Environmental Entomology 26(2): 215-222.

The effects of seasonal flooding on larvae of Chironomus stigmaterus Say were studied in 12 managed wetlands of the Sacramento-San Joaquin River estuary, California. Six pairs of wetlands were flooded artificially on 5 and 19 August; 2, 16, and 30 September; or 14 October 1991. One member of each wetland pair was dominated by pickleweed, Salicornia virginica L., and the other by alkali bulrush, Scirpus robustus Pursh. Densities of midge larvae were significantly higher in wetlands flooded earlier than later. The numerical patterns exhibited by C. stigmaterus populations suggest opportunistic responses. Midges thrived in habitats 1st flooded in August, yet such habitats would not naturally exist in the California Mediterranean climate because the rainy season does not begin until late autumn. Although this midge probably evolved in freshwater habitats, it readily colonized habitats dominated by pickleweed, a salt marsh plant. Populations of the beetle Berosus ingeminatus d'Orchymont also were higher in pickleweed than in alkali bulrush habitats; these predators appeared to affect midge populations in pickleweed wetlands during autumn. Because C. stigmaterus larvae are an important food resource for dabbling ducks, their opportunistic response to the artificial conditions in California seasonal wetlands has benefits in terms of waterfowl management.

Batzer, D. P., M. McGee, et al. (1993). "Characteristics of invertebrates consumed by mallards and prey response to wetland flooding schedules." Wetlands 13(1): 41-49.

The authors examined characteristics of the invertebrates consumed by mallards (Anas platyrhynchos) and green-winged teals (Anas crecca) and responses of these invertebrates to manipulations of flooding date in Suisun Marsh, Solano County, CA. Numbers of Chironomus stigmaterus midge larvae (Chironomidae) and Eogammarus confervicolus amphipods (Gammaridae) in mallard esophageal samples were positively correlated with abundance of these invertebrates in wetlands. Mallards primarily consumed large midge larvae (fourth instars) and amphipods (> 5 mm in length). Smaller green-winged teals consumed smaller midges. Mallards consumed few Trichocorixa verticalis water boatmen (Corixidae) or Cricotopus sylvestris midge larvae, despite their being abundant. Wetlands first flooded in early September had higher winter populations of amphipods and Berosus ingeminatus beetle larvae (Hydrophilidae) than wetlands first flooded in late October. Late-winter abundance of benthic C. stigmaterus midge larvae was highest at 40-cm water depths in the former habitats and at 20-cm depths in the latter habitats.

Bauer, B. O., M. S. Lorang, et al. (2002). "Estimating Boat-Wake-Induced Levee Erosion using Sediment Suspension Measurements." Journal of Waterway, Port, Coastal and Ocean Engineering 128(4): 152-162.

The subaqueous portion of a levee bank in the Sacramento - San Joaquin River Delta of central California was instrumented to quantify the impact of boat-generated waves. Typical erosion rates associated with recreational craft are too small for direct measurement of bank retreat on a per-boat-passage basis; therefore, two independent analytical methods of estimating linear erosion were developed based on colocated suspended sediment concentration and velocity time series. The algorithms were tested using data measured during a field experiment in which a 7.5 m boat was driven past the site over a range of speeds to generate waves of varying size. A cross-shore array of electromagnetic current meters and optical back-scatterance sensors measured the character of boat-generated waves and the resultant sediment suspension. In near-bank, shallow-water (d < 0.5 m) locations, sediment suspension was closely correlated with the primary boat-wake waves (H sub(max) < 0.21 m), indicating that maximum near-bottom orbital velocities were sufficient to erode the fine-grained (mud-silt) bottom materials. Suspension events were short lived (order of 1-5 min), despite very long particle settling times (order of hours), because river currents swept the suspension plumes downstream. This implies negligible sedimentation and resuspension locally. Both algorithms produced strikingly similar erosion estimates, and these values (0.01-0.22 mm/boat passage) compare favorably with direct measurements of cumulative bank erosion in response to multiple, sequential boat passages. Field conditions for which the algorithms are appropriately applied are discussed.

Baxa, D. V., I. Flores, et al. (2010). Microcystis in the San Francisco Estuary: Abundance of toxic and nontoxic strains, initial establishment of laboratory cultures, and localization in fish exposed to blooms and spiked diets. 6th Biennial Bay–Delta Science Conference. Workshop presentation at Sacramento Convention Center, Sacramento, California.

Microcystin (MC) levels in the San Francisco Estuary (SFE) – Delta, produced mainly by recurring Microcystis aeruginosa, are theoretically governed by two key mechanisms in the ecosystem: regulating the abundance of toxic strains, and regulating microcystin (MC) production from toxin-producing strains. Two studies were initiated to address these assumptions. First, the abundance of MC-producing (toxic) and MC-lacking (nontoxic) Microcystis were determined during the bloom season in the SFE in 2007. The proportion of toxic and nontoxic Microcystis across sites and stages of bloom development in the estuary was assessed by qPCR that we developed based on local Microcystis strains. Second, pilot studies are in progress to generate mass cultures of local Microcystis species. Establishing laboratory cultures is central to evaluating the role of key environmental factors on the growth, survival, and MC production of local Microcystis strains. Initial results on abundance of toxic and nontoxic strains of Microcystis cultures from the estuary will be described. Lastly, retrospective analyses of key species in the Delta such as delta smelt and striped bass previously exposed to blooms in 2005 were initiated to determine the fate of Microcystis among these fish. In parallel, biological effects of Microcystis on threadfin shad and Sacramento splittail were examined by feeding Microcystis-spiked diets in the laboratory. Using DNA probes specific to local Microcystis and specific antibodies to MC-LR, localization of Microcystis and MCs were analyzed by in situ hybridization and immunohistochemistry, respectively among fish exposed in the field and in the laboratory. Monitoring blooms using qPCR can reveal trends in the sources and magnitude of toxic and nontoxic Microcystis in the estuary. As such, rapid risk assessment and strategies can be designed to manage the adverse effects of cyanobacterial blooms to the ecosystem and its fishery resources. Forthcoming evaluation of manipulated physicochemical stressors using Microcystis cultures will provide the knowledge to predict conditions that will enhance or decrease MC synthesis. Fish exposed to blooms and Microcystis-spiked diets demonstrated the bioaccumulation of MCs in high trophic levels and that Microcystis uptake can be mediated through their zooplankton prey. These results will lay the groundwork for future studies designed to address how zooplankton and other primary food resources of larval pelagic fish will respond to expanding Microcystis blooms.

Baxa, D. V., T. Kurobe, et al. (2010). "Estimating the abundance of toxic Microcystis in the San Francisco Estuary using quantitative real-time PCR." Harmful Algae 9(3): 342-349

Developing an effective and rapid method to identify and estimate the abundance of Microcystis is warranted in the San Francisco Estuary (SFE) in view of expanding cyanobacterial blooms dominated by Microcystis spp. Blooms that occurred in the estuary from July to September 2007 were initially assessed using a standard polymerase chain reaction (PCR) employing primers designed for the conserved Microcystis-specific 16S ribosomal DNA (rDNA) region. The presence of microcystin-producing (MC+) toxic Microcystis was observed in cyanobacterial and water samples as shown by the amplification of the MC toxin synthetase genes mcyB and mcyD by standard PCR. The goal of this study was to develop a real-time quantitative PCR (qPCR) based on the 16S rDNA and mcyD gene sequences of Microcystis found in the SFE to quantify the proportion of toxic Microcystis with mcyD genes among total Microcystis or cyanobacterial population. Cyanobacterial samples collected by diagonal net tows of the water column showed that the ratio of gene copies was dominant for Microcystis among cyanobacteria (28–96%), and Microcystis carrying mcyD genes formed 0.4–20% of the total Microcystis spp. Total Microcystis was also abundant (7.7 × 104 to 9.9 × 10^7 cells L−1) in ambient surface waters, and the range of Microcystis cell equivalents with mcyD genes (4.1 × 102 to 2.2 × 107 cells L−1) indicated a large variation in the ratio of toxic Microcystis among total Microcystis (0.01–27%). Differences in the proportion of toxic and nontoxic Microcystis, as deduced from the cell equivalents of total Microcystis, were observed across the sampling locations and seasons where concentrations of total MCs

(0.007-10.81 µg/L) also varied. By revealing trends in the sources and magnitude of toxic and nontoxic Microcystis, qPCR can contribute to rapid risk assessment and prediction of strategies designed to manage the adverse effects of cyanobacterial blooms in the SFE.

Baxter, R. (1999). "Status of Sacramento splittail in California." California Fish and Game 85: 28-30.

Baxter, R. (2010). Are juvenile longfin smelt abandoning the Suisun Bay neighborhood?... the rest of the story. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The longfin smelt is one of four pelagic fish species whose abundance declined sharply after 2001 and has generally remained low since based on Fall Midwater Trawl Survey sampling. These fish declines and associated changes in the upper estuary food web became known as the Pelagic Organism Decline (POD). Before the POD decline and after the establishment of Corbula amurensis, longfin smelt shifted their distribution toward higher salinity water during summer and fall and away from Suisun Bay. I examine this distribution shift in more detail and whether such a shift could partially explained some of the declining abundance during the POD years, as would be the case if a larger fraction of the population inhabited regions outside the Fall Midwater Trawl Survey sampling area. I also provide evidence of a recent increase in the age structure of spawners and conjecture regarding how this shift came about, its potential link to a shift in distribution and its effect on total fecundity.

Baxter, R., R. Breuer, et al. (2008). Pelagic Organism Decline Progress Report: 2007 Synthesis of Results. Sacramento, Interagency Ecological Program for the San Francisco Estuary.

Baxter, R., K. Hieb, et al. (1999). Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California. Sacramento, CA, Interagency Ecological Program for the Sacramento-San Joaquin Estuary.
The San Francisco Estuary is the largest estuary on the west coast of North America. Located somewhat more than halfway up the California coast from the Mexican border, it is the natural exit point of 4% of California's freshwater outflow. This water is a prized commodity in California, sought after by farmers for food production, municipalities for people and industries, and environmentalists for the rich, but in some cases threatened, fish and invertebrate resources of the estuary. To capture the water for human needs, dams, aqueducts, canals, and pumpingts have been constructed to pump water out of the estuary and transport it to the San Francisco Bay area, the San Joaquin Valley, and southern California. These human alterations affect the life of the estuary by reducing the freshwater flow that creates the estuary. Freshwater flowing seaward, mixing with ocean water, creates habitats that attract coastal fish to spawn, while providing low salinity habitat for the rearing of their young. Other fish, such as salmon, detect the scents of their home rivers in the freshwater outflow and enter the estuary on their spawning migrations. Still other fish and many open water and bottom crustaceans and shellfish reside in the brackish water regions all their lives. California's 2 largest rivers, the Sacramento and the San Joaquin, merge to form the estuary. They drain part of the Sierra Nevada and Cascade mountains and form a large and convoluted delta in the Central Valley. The delta consists of about 1,100 km of river channels and sloughs that cover an area of about 3,000 km super(2) and drain into Suisun Bay on the edge of the low mountains of the Coast Range. A 100-m deep ship channel runs along the south side of Suisun Bay. To its north are extensive shoals. West of Suisun Bay the deep trough of Carquinez Strait breaches the Coast Range and connects Suisun Bay with the much larger San Pablo Bay. Most of San Pablo Bay is a broad shoal, only the ship channel on its south-eastern side provides deep water. San Francisco Bay is the last of the bays and empties into the Pacific Ocean through the Golden Gate. Its small northern quarter is termed Central Bay. Although small, it is the deepest of the bays with shoals confined mainly to its eastern side. The long southeast leg of San Francisco Bay is called South Bay. It has a central channel that narrows southwards and broad shoals on either side of the channel.

Baxter, R., M. L. Nobriga, et al. (2010). The protected?, the bad, and the ugly: use of a coupled hydrodynamic-particle tracking model & 3 Years of low outflow hydrology to evaluate entrainment risk for longfin smelt larvae in the Delta. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Beach, D., T. Yu, and C. Kitting (2010). Growth rates of eelgrass (Zostera marina) in San Francisco Bay and Tomales Bay, and associated animal population densities. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Highest population densities of epibenthic macroinvertebrate animals are associated with dense cover in one of the most productive ecosystems on earth, seagrass meadows. Seagrasses are a valuable commodity, providing numerous important ecosystem services including being prolific primary producers, serving as a nursery for valuable fisheries and a food resource for thousands of fish, bird, and invertebrate species. In addition, they moderate currents and wave action protecting coasts from erosion, and also sequester a vast amount of carbon. Being flowering plants, seagrasses require bright light for photosynthesis but human activities inadvertently are decreasing light availability, diminishing seagrass habitats. By determining light limits for optimum growth conditions can be improved, thus allowing seagrass to provide its wide variety of services. San Francisco Bay is 40 times larger than Tomales Bay yet has only 1/3 the total seagrass cover, possibly due to a heavy pollutant load and murkier water compared to Tomales Bay. Historically, Tomales Bay has been quite pristine with clear, relatively unpolluted water; these conditions would provide the much-needed bright light for seagrass growth. Associated invertebrate animal population densities also are hypothesized to be higher in Tomales Bay due to its vast amount of seagrass meadows and lack of pollutants. During winter through spring, 2009-2010, we monitored growth rates of eelgrass (Zostera marina), the predominant seagrass in San Francisco Bay and Tomales Bay, in different local environments representing a variety of light conditions. We also monitored associated invertebrate populations there. Surprisingly, detectably higher growth rates of eelgrass, and somewhat higher eelgrass animal diversities, occurred in San Francisco Bay compared with Tomales Bay. Our upcoming, proposed comparisons of historical data at such sites might detect why San Francisco Bay often has high eelgrass growth rates and invertebrate abundances.

Beck, N. G., K. W. Bruland, et al. (2002). "Short-term biogeochemical influence of a diatom bloom on the nutrient and trace metal concentrations in South San Francisco bay microcosm experiments." Estuaries 25: 1063-1076.
Two laboratory microcosm experiments were conducted to mimic an annual spring diatom bloom in South San Francisco Bay by isolating the phytoplankton community from the benthic grazing pressure to induce a phytoplankton bloom. The purpose of these experiments was to isolate the impact of a spring diatom bloom on the nutrient and trace metal geochemical cycling. Microcosms were created in 2.5 L incubation bottles and subjected to one of 4 treatments (control, copper [Cu] addition, manganese [Mn] addition, and both Cu and Mn addition) to investigate the toxicity of Cu on the resident plankton and the potential antagonistic effects of Mn on reducing Cu toxicity. Dissolved macronutrient (nitrate + nitrite, phosphate, and silicate), and dissolved and particulate trace metal (Cu, Ni, Mn) concentrations were monitored in the grow-out incubations on a daily basis. Chlorophyll a concentrations were also monitored over the course of the experiment and used to calculate diatom-specific growth rates. In the experiments containing ambient South San Francisco Bay surface waters, average specific growth rates were on the order of 1.1 d(-1). The induced diatom blooms resulted in significant removal of macronutrients from the microcosms over the course of the experiments. Our research supports previous suggestions that dissolved Ni and Cu concentrations in South San Francisco Bay have a very low biological availability as a result of organic chelation. Ni(EDTA)(2-) has been found to be the dominant dissolved Ni species by other researchers and Cu speciation analyses from this study and others indicate that > 99% of the dissolved Cu in South San Francisco Bay is strongly chelated as CuL1. The free cupric ion concentration was on the order of 10(-12) M. Marked removal of dissolved Mn was observed in the control treatments, well exceeding

expected dissolved Mn removal by diatom uptake. Additions of 375 nM Cu resulted in the complete titration of the chelating ligand (L-1) concentrations. The elevated [Cu2+] (approximate to 10(-8) M) appeared to have a toxic effect on the diatom community observed in the significant decreases in their specific growth rates (mu = 0.4 d(-1)). The suppression of dissolved Mn removal from solution was also observed in treatments spiked with high levels of dissolved Cu, providing support that Mn precipitation was due to biologically mediated oxidation not phytoplankton assimilation. The observed geochemical behavior in the concurrent Cu and Mn addition treatments provide evidence in support of Mn alleviation of Cu toxicity. The biological role in the ambient short-term biogeochemical cycling of Cu and Ni in South San Francisco Bay appears to be minimal due to the inert character of the organic ligand-metal complexes. A significant portion of the annual macronutrient and Mn cycling occurs as a result of spring diatom blooms in South San Francisco Bay.

Beggel, S., R. Connon, et al. (2011). "Changes in gene transcription and whole organism responses in larval fathead minnow (Pimephales promelas) following short-term exposure to the synthetic pyrethroid bifenthrin." Aquatic Toxicology 105(1–2): 180-188.

Beggel, S., I. Werner, et al. (2010). "Sublethal toxicity of commercial insecticide formulations and their active ingredients to larval fathead minnow (Pimephales promelas) " Science of The Total Environment 408(16): 3169-3175.

Toxic effect concentrations of insecticides are generally determined using the technical grade or pure active ingredient. Commercial insecticide formulations, however, contain a significant proportion (> 90%) of so-called inert ingredients, which may alter the toxicity of the active ingredient(s). This study compares the sublethal toxicity of two insecticides, the pyrethroid bifenthrin, and the phenylpyrazole fipronil, to their commercial formulations, Talstar® and Termidor®. Both insecticides are used for landscape treatment and structural pest control, and can be transported into surface water bodies via stormwater and irrigation runoff. We used larval fathead minnow (Pimephales promelas), to determine effects on growth and swimming performance after short-term (24 h) exposure to sublethal concentrations of pure insecticides and the respective formulations. Significantly enhanced 7 d growth was observed at 10% of the 24 h LC10 (53 µg L−1) fipronil. Swimming performance was significantly impaired at 20% of the 24 h LC10 (0.14 µg L−1) of bifenthrin and 10% of the 24 h LC10 of Talstar® (0.03 µg L−1). Fipronil and Termidor® led to a significant impairment of swimming performance at 142 µg L−1 and 148 µg L−1 respectively, with more pronounced effects for the formulation. Our data shows that based on dissolved concentrations both formulations were more toxic than the pure active ingredients, suggesting that increased toxicity due to inert ingredients should be considered in risk assessments and regulation of insecticides.

Beissinger, S., P. Girard, J.Y. Takekawa, and L. Hall (2010). Connectivity within and between Black Rail metapopulations in the Bay-Delta and Sierra Foothills: Implications for persisting under rising sea-levels. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Whether Bay-Delta wetland species persist as sea-levels rise in response to climate warming will depend on the degree that existing wetland size and distribution change and the ability of species to disperse to newly created sites. While many wetland birds are strong-fliers, the state-threatened Black Rail is likely a poor disperser because it flies weakly, has a highly disjunct distribution, and lives its entire life under dense marsh vegetation. We used mitochondrial and microsatellite markers to determine the species’ status in California, and to evaluate levels of connectivity within and among Bay-Delta metapopulations. Analyses of individuals from the recently discovered metapopulation in the Sierra Nevada Foothills, and those in San Francisco Bay and Imperial Valley suggest a historical presence of the species in the Foothills. Foothills birds, while connected by migration to its nearest known population in San Francisco Bay, are comprised of individuals with a unique genetic composition and perhaps different dispersal behaviour. Mitochondrial DNA and microsatellite composition were similar between the Foothills and SF Bay populations but both areas have diverged strongly from the

Imperial Valley population. SF Bay had greater genetic diversity but an estimated effective population size that was similar to the Foothills population. Random mating was indicated by genotypic frequencies in the Foothills but local substructure among marshes and inbreeding depression were detected in SF Bay, suggesting less dispersal among the larger but more isolated sites in this metapopulation. Both SF Bay and the Foothills show departure from mutation-drift equilibrium in accordance with historic population declines. While our results should be considered preliminary, they suggest how new studies may be useful for understanding the species' capacity to respond to future seas-level change in Bay-Delta and how the creation of stepping-stone wetlands through current restoration processes could contribute to persistence.

Benigno, G. M., and T.R. Sommer (2008). "Just add water: sources of chironomid drift in a large river floodplain." Hydrobiologia 600: 297-305.
Although seasonal floodplains represent one of the most dynamic and productive of aquatic ecosystems, the sources of this productivity are poorly understood. We examined composition and sources of chironomid drift in the Yolo Bypass, the primary floodplain of the Sacramento River. We found that invertebrate drift during winter floodplain inundation is dominated by a single species, the newly identified chironomid Hydrobaenus saetheri (Diptera: Chironomidae). In order to determine sources of chironomids in the Yolo Bypass, invertebrates were sampled from several potential sources prior to and during initial floodplain inundation. Rehydration of dried floodplain sediments from several locations showed that H. saetheri dominated insect emergence from this colonization pathway. By contrast, H. saetheri was not a substantial component of inundated floodplain ponds or of tributary inputs to the floodplain. We conclude that the initial pulse of invertebrate abundance in Yolo Bypass floodwaters is dominated by chironomid emergence from sediments in multiple regions of the floodplain.

Benigno, G. M., T.R. Sommer, and N. van Ark (2010). Effects of a restored freshwater tidal wetland complex on habitat for imperiled native fish. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Benigno, G. M., T.R. Sommer, and N. van Ark (2010). Effects of a restored freshwater tidal wetland complex on pelagic habitat for imperiled native fish. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The recent collapse of pelagic fish populations in the Sacramento-San Joaquin Delta has led to increased interest in habitat restoration. Successful tidal wetland restoration has occurred naturally in the northern Delta at Liberty Island, where a levee breach inundated the island in 1998 and a highly productive tidal freshwater wetland has developed. Liberty Island and its surrounding sloughs, known as the Cache Slough Complex, are now considered key habitat for endangered native fish species. The Cache Slough Complex is a priority area for future habitat restoration efforts to protect and enhance native delta fishes. In order to develop a baseline understanding of the system, this study examines the hydrodynamic “footprint” of Liberty Island in the Cache Slough complex. Continuous monitoring of flow, temperature, turbidity, and salinity is coupled with quarterly sampling of biological resources over spring and neap tidal cycles. We report seasonal diel patterns in phytoplankton and zooplankton abundance from Liberty Island and surrounding sloughs. Chlorophyll concentration is higher in western sloughs than in the main channels of the Cache Slough Complex. Zooplankton abundance exhibits tidal and seasonal patterns, and overall abundance is high compared with other freshwater regions of the delta. Understanding the patterns of hydrodynamics and productivity is important to describe the habitat of pelagic fishes including delta smelt, and will help to identify and plan future restoration projects in the region.

Bennett, W. A., D.A. Ostrach, and D.E. Hinton. (1995). "Larval striped bass condition in a drought-stricken estuary: evaluating pelagic food-web limitation." Ecological Applications 5(3): 680-692.
Estuarine food webs are frequently altered by human interventions, including freshwater diversions, toxic compounds, and introduced species. From 1988 through

1991 we examined the external morphological and internal histopathologic condition of larval striped bass (Morone saxatilis) to evaluate the potential importance of starvation to fish recruitment in the San Francisco Bay estuary. During a recent drought (1987-1992), fish populations declined markedly, concurrent with dramatic reductions in phytoplankton and zooplankton food for larval fishes. Such patterns suggest pelagic food is limited during times of low freshwater input; therefore, larval starvation may limit recruitment. However, toxic compounds in agricultural runoff are also less diluted in low-outflow years, enhancing their potential impact. Histopathology enabled us to identify their possible effects. In the laboratory, indices of larval morphology and eye and liver tissue condition reflected starvation after 2 d of food deprivation. From 1988 through 1991 >90% of 980 field-caught specimens were classified morphologically as feeding larvae. Histopathological evaluation indicated that all field-caught specimens (N = 500) had food in their guts and lacked tissue alterations consistent with starvation. However, liver alterations consistent with toxic exposure were seen in 26-30% of the field-caught larvae from 1988 through 1990, dropping to 15% in 1991. While our findings implicate toxic exposure as a factor in the relationship between low freshwater input and poor year-class success of striped bass, reductions of toxic runoff and improvement in larval liver condition in 1991 did not improve larval survival. This suggests the potentially greater importance of interactions with food limitation and predation as well as the futility of pursuing single-factor explanations for recruitment failure. The potential obfuscation of food limitation by toxic exposure also indicates the need for interdisciplinary approaches to distinguishing anthropogenic intervention from estuarine food-web processes.

Bennett, W. A., and P. B. Moyle. (1996). Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento San Joaquin Estuary. San Francisco Bay: The urbanized estuary. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science: 519-542.

Bennett, W. A., W.J. Kimmerer, and J.R. Burau. (2002). "Plasticity in vertical migration by native and exotic estuarine fishes in a dynamic low-salinity zone." Limnology and Oceanography 47(5): 1496-1507.
We investigated the degree of flexibility in retention strategies of young fishes in the low-salinity zone (LSZ) of the San Francisco Estuary during years of highly variable river flow. We conducted depth-stratified sampling over three full tidal cycles in each year from 1994 to 1996. In 1994, exotic striped bass (Morone saxatilis), native longfin smelt (Spirinchus thaleichthys), and exotic yellowfin goby (Acanthogobus flavimanus) migrated tidally, occurring near the surface on flood tides and near the bottom on ebb tides. This strategy may have facilitated retention, because landward residual currents were absent in this drought year. During 1995, this behavior persisted for striped bass and yellowfin goby, even though landward residual currents were present under high river-flow conditions. In moderate river-flow conditions (1996), longfin smelt again migrated tidally, whereas at another station adjacent to shallow bays, longfin smelt, striped bass, and native delta smelt (Hypomesus transpacificus) migrated on a reverse diel cycle, occurring near the surface by day and at depth by night. Reverse diel migration may facilitate horizontal transport and retention. Therefore, young fishes appeared to be behaviorally flexible in different environmental conditions to maximize retention. Vertical migrations may also enhance feeding success because zooplankton prey similarly migrated in the LSZ. Our study underscores the value of interdisciplinary studies in a variety of environmental conditions to decipher the range of organism behaviors promoting transport and retention in optimal habitats.

Bennett, W. A. (2005). "Critical assessment of the delta smelt population in the San Francisco Estuary, California." San Francisco Estuary and Watershed Science 3(2): Issue 2 Article 1.
The delta smelt (Hypomesus transpacificus) is a small and relatively obscure fish that has recently
risen to become a major focus of environmental concern in California. It was formally abundant in the
low-salinity and freshwater habitats of the northeastern San Francisco Estuary, but is now listed as

threatened under the Federal and California State Endangered Species Acts. In the decade following
the listings scientific understanding has increased substantially, yet several key aspects of its biology
and ecological relationships within the highly urbanized estuary remain uncertain. A key area of controversy
centers on impacts to delta smelt associated with exporting large volumes of freshwater from
the estuary to supply California's significant agricultural and urban water demands. The lack of appropriate
data, however, impedes efforts to resolve these issues and develop sound management and
restoration alternatives.
Delta smelt has an unusual life history strategy relative to many fishes. Some aspects of its biology are
similar to other coastal fishes, particularly salmonids. Smelts in the genus, Hypomesus, occur throughout
the Pacific Rim, have variable life history strategies, and are able to adapt rapidly to local environments.
By comparison, delta smelt has a tiny geographic range being confined to a thin margin of low
salinity habitat in the estuary. It primarily lives only a year, has relatively low fecundity, and pelagic larvae;
life history attributes that are unusual when compared with many fishes worldwide. A small proportion
of delta smelt lives two years. These individuals are relatively highly fecund but are so few in
number that their reproductive contribution only may be of benefit to the population after years of
extremely poor spawning success and survival. Provisioning of reproductive effort by these older fish
may reflect a bet-hedging tactic to insure population persistence.
Overall, the population persists by maximizing growth, survival, and reproductive success on an
annual basis despite an array of limiting factors that can occur at specific times and locations. Variability
in spawning success and larval survival is induced by climate and other environmental and anthropogenic
factors that operate between winter and mid-summer. However, spawning microhabitats with
egg deposition have not been discovered. Spawning success appears to be timed to lunar periods
within a water temperature range of about 15 to 20°C. Longer spawning seasons in cooler years can
produce more cohorts and on average higher numbers of adult delta smelt. Cohorts spaced in time
have different probabilities of encountering various sources of mortality, including entrainment in freshwater
export operations, pulses of toxic pesticides, food shortages and predation by exotic species.
Density dependence may provide an upper limit on the numbers of juvenile delta smelt surviving to the
adult stage. This may occur during late summer in years when juvenile abundance is high relative to
habitat carrying capacity. Factors defining the carrying capacity for juvenile delta smelt are unknown,
but may include a shrinking volume of physically suitable habitat combined with a high density of competing
planktivorous fishes during late summer and fall.

Bennett, W. A., and P.B. Moyle (2010). Application of dynamic regime theory to sssess the extent of estuarine ecosystem change: oh, you don't know, the shape I'm in. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the

Sacramento Convention Center, Sacramento, California.
The concept of regime change originated separately in oceanography and in ecological theory. Ideological and logistical differences led to a focus in oceanography on identifying associations and breakpoints among time series, i.e. correlations; whereas, a more process-based perspective developed in ecology due to opportunities for manipulative studies, e.g. in lakes, and developments in population and system modeling. To aid in unifying these two conceptual lineages, and better assess the human role in estuarine change, we evaluated the extent to which dynamic regime changes have occurred in the San Francisco Estuary and Delta. We focus our evaluation at various regional and whole-system scales, using a variety of long-term data sets extending back to the 1970s. First we examine relative changes in various ecosystem constituents in phase space to explore patterns in dynamic behavior consistent with a regime shift, and then apply two techniques designed to detect "leading indicators" of a pending regime shift; i.e. evidence for the slowing down of system dynamics. Our results provide robust support for a regime shift occurring in the Delta region in about 2000-2001. Although less evidence was observed for similar shifts in other regions or across the entire estuary, the likelihood of future regime shifts was bolstered by evidence for leading indicators of change in near-by regions such as Suisun Marsh. Overall, this study underscores the fundamental nature of ecosystems as continuously changing, which in highly human altered systems is almost always irreversible. Thus, Delta policies relying on historical abundances as baselines, or targets for restoration of desired species have little relevance in this new regime. Ongoing efforts to restore or rehabilitate native species are likely to fail without carefully targeted and prolonged investments to reestablish habitat conditions that reflect the life history characteristics of native and desirable fishes.

Bennett, W. A. (2010). Should I stay or should I go? tides, turbidity and triggers for Delta Smelt migration. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Bennett, W. A., S.J. Teh, and J.A. Hobbs (2010). What really happened to delta smelt? Water exports and habitat conditions drive patterns of selective mortality at ecological and possibly evolutionary scales. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Decades of research attest to the futility of "silver bullet" explanations for the collapse of fish populations. Multiple interactive factors typically act subtly in systematic or stochastic ways to reduce survival of individuals before an effect is observed on the population. Moreover, if mortality from human or natural sources repeatedly affects certain individuals over multiple generations, it can drive evolution. We addressed these issues by implementing an approach for quantifying age and growth (from otoliths), with indicators of poor feeding success and exposure to toxic chemicals, (from liver and gonad histopathology), for individual delta smelt caught during routine monitoring. Multiple measurements were made on about 1,500 individuals from 1999-2007, the period of decline. We evaluated patterns in size selective mortality among years, while controlling for temperature effects on growth, with the relative influences of environmental conditions (freshwater outflow) and human activities (toxic exposure, water export operations) using nonlinear mixed models. Before the decline (1999-2001) individuals surviving to the adult stage (in December) were generally larger at hatching, or had higher than average growth rates, and were spawned in early spring. However, after the decline (2005-2007), patterns of selective mortality were more complex and generally opposite. The few early-spawned adult survivors initially grew slower, but then faster than average after mid-summer, and the mean size of adults also declined. Although these patterns are consistent with adverse effects on early spawned larvae by water export operations, a possible evolutionary effect may be confounded by the overall deterioration of summer habitat conditions that also occurred over time. Overall, our findings have significant implications for management of water export operations, because this interactive sequence of human and natural factors likely played a significant role in the decline of delta smelt.

Bennett, W. A., W. J. Kimmerer, et al. (2002). "Plasticity in vertical migration by

native and exotic estuarine fishes in a dynamic low-salinity zone." Limnology and Oceanography 47: 1496–1507.
We investigated the degree of flexibility in retention strategies of young fishes in the low-salinity zone (LSZ) of the San Francisco Estuary during years of highly variable river flow. We conducted depth-stratified sampling over three full tidal cycles in each year from 1994 to 1996. In 1994, exotic striped bass (Morone saxatilis), native longfin smelt (Spirinchus thaleichthys), and exotic yellowfin goby (Acanthogobus flavimanus) migrated tidally, occurring near the surface on flood tides and near the bottom on ebb tides. This strategy may have facilitated retention, because landward residual currents were absent in this drought year. During 1995, this behavior persisted for striped bass and yellowfin goby, even though landward residual currents were present under high river-flow conditions. In moderate river-flow conditions (1996), longfin smelt again migrated tidally, whereas at another station adjacent to shallow bays, longfin smelt, striped bass, and native delta smelt (Hypomesus transpacificus) migrated on a reverse diel cycle, occurring near the surface by day and at depth by night. Reverse diel migration may facilitate horizontal transport and retention. Therefore, young fishes appeared to be behaviorally flexible in different environmental conditions to maximize retention. Vertical migrations may also enhance feeding success because zooplankton prey similarly migrated in the LSZ. Our study underscores the value of interdisciplinary studies in a variety of environmental conditions to decipher the range of organism behaviors promoting transport and retention in optimal habitats.

Bennett, W. A. and P. B. Moyle (1996). Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento-San Joaquin Estuary. San Francisco Bay: The Ecosystem. J. T. Hollibaugh. San Francisco, AAAS: 519-542.

Bennett, W. A., D. J. Ostrach, et al. (1995). "Larval striped bass condition in a drought-stricken estuary: evaluating pelagic food-web limitation." Ecological Applications 5: 680-692.
Estuarine food webs are frequently altered by human interventions, including freshwater diversions, toxic compounds, and introduced species. From 1988 through 1991 we examined the external morphological and internal histopathologic condition of larval striped bass (Morone saxatilis) to evaluate the potential importance of starvation to fish recruitment in the San Francisco Bay estuary. During a recent drought (1987-1992), fish populations declined markedly, concurrent with dramatic reductions in phytoplankton and zooplankton food for larval fishes. Such patterns suggest pelagic food is limited during times of low freshwater input; therefore, larval starvation may limit recruitment. However, toxic compounds in agricultural runoff are also less diluted in low-outflow years, enhancing their potential impact. Histopathology enabled us to identify their possible effects. In the laboratory, indices of larval morphology and eye and liver tissue condition reflected starvation after 2 d of food deprivation. From 1988 through 1991 >90% of 980 field-caught specimens were classified morphologically as feeding larvae. Histopathological evaluation indicated that all field-caught specimens (N = 500) had food in their guts and lacked tissue alterations consistent with starvation. However, liver alterations consistent with toxic exposure were seen in 26-30% of the field-caught larvae from 1988 through 1990, dropping to 15% in 1991. While our findings implicate toxic exposure as a factor in the relationship between low freshwater input and poor year-class success of striped bass, reductions of toxic runoff and improvement in larval liver condition in 1991 did not improve larval survival. This suggests the potentially greater importance of interactions with food limitation and predation as well as the futility of pursuing single-factor explanations for recruitment failure. The potential obfuscation of food limitation by toxic exposure also indicates the need for interdisciplinary approaches to distinguishing anthropogenic intervention from estuarine food-web processes.

Benville, P., J. Whipple, et al. (1985). "Acute toxicity of seven alicyclic hexanes to striped bass, Morone saxatilis, and bay shrimp, Crangon fransicorum, in seawater." California Fish and Game 71: 132-140.
Studies were concerned with the acute toxicities of the simplest alicyclics in comparison to their counterparts in the aromatic series. The alicyclic compounds were cyclohexane, methylcyclohexane and four dimethylcyclohexanes (1,1; 1,2; 1,3;

and 1,4). Acute toxicities after 24 and 96 h exposures to seven alicyclic hexanes were determined for striped bass and one of their major food organisms, the bay shrimp, Crangon franciscorum . The 96 h LC sub(50)s for striped bass and bay shrimp ranged from 3.2 to 9.3 mu l/l and from 1.0 to 6.2 mu l/l, respectively. Solubilities of these alicyclics in seawater and freshwater were determined since information in the literature was limited. Solubility was inversely related to the complexity of the alicyclic structure and ranged from 5.3 to 62 mu l/l in distilled water and from 4.6 to 44 mu l/l in seawater. Alicyclics were generally more soluble in distilled water than in seawater.

Bergamaschi, B., J. Fleck, B. D. Downing, E. Boss, B.Pellerin, N. Ganju, D. Schoellhamer, W. Heim, M. Stephenson, and R. Fujii (2011). " Methyl mercury dynamics in a tidal wetland quantified using in situ optical measurements." Limnology and Oceanography 56(doi: 10.4319/lo.2011.56.4.0000): 17.
a) Tidal wetlands are significant sources of methylmercury mercury
b) Simple, economic methods can be used to monitor the flux of methylmercury in tidal systems
c) Wetland restorations should be designed to minimize export of methylmercury to the estuary

Bergamaschi, B., J. Fleck, B. Downing, E. Boss, B.Pellerin, N. Ganju, D. Schoellhamer, A. Byington, W. Heim, M. Stephenson, and R. Fujii (2012). "Mercury Dynamics in a San Francisco Estuary Tidal Wetland: Assessing Dynamics Using In Situ Measurements." Estuaries and Coasts 35: 13.
We used high-resolution in situ measurements of turbidity and fluorescent dissolved organic matter (FDOM) to quantitatively estimate the tidally driven exchange of mercury (Hg) between the waters of the San Francisco estuary and Browns Island, a tidal wetland. Turbidity and FDOM—representative of particle-associated and filter-passing Hg, respectively—together predicted 94 % of the observed variability in measured total mercury concentration in unfiltered water samples (UTHg) collected during a single tidal cycle in spring, fall, and winter, 2005–2006. Continuous in situ turbidity and FDOM data spanning at least a full spring-neap period were used to generate UTHg concentration time series using this relationship, and then combined with water discharge measurements to calculate Hg fluxes in each season. Wetlands are generally considered to be sinks for sediment and associated mercury. However, during the three periods of monitoring, Browns Island wetland did not appreciably accumulate Hg. Instead, gradual tidally driven export of UTHg from the wetland offset the large episodic on-island fluxes associated with high wind events. Exports were highest during large spring tides, when ebbing waters relatively enriched in FDOM, dissolved organic carbon (DOC), and filter-passing mercury drained from the marsh into the open waters of the estuary. On-island flux of UTHg, which was largely particle-associated, was highest during strong winds coincident with flood tides. Our results demonstrate that processes driving UTHg fluxes in tidal wetlands encompass both the dissolved and particulate phases and multiple timescales, necessitating longer term monitoring to adequately quantify fluxes.

Bergamaschi, B. A., B. Pellerin, B. Downing, T. Kraus, J.F. Saraceno, J. Fleck, J. Shanley, G. Aiken, E. Boss, and R. Fujii (2010). Seeing the light: Applications of in situ optical measurements for understanding water quality in rivers, deltas, and estuaries. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
A critical challenge for understanding and quantifying the causes and environmental impacts of degraded water quality is making measurements at the time scales in which changes occur in aquatic systems. Traditional approaches for data collection (daily to monthly discrete sampling) are often limited by analytical and field costs, site access, and logistical challenges particularly for long-term sampling at a large number of sites. In situ optical instrumentation offers an opportunity to help overcome these difficulties. The ability to make optical measurements in situ has been around for more than 50 years, but much of the work on in situ absorbance and fluorescence using commercially-available instruments has taken place in only the last few years. We present several examples that highlight the application of in situ measurements for understanding dynamics in river and

estuary systems at intervals of minutes to hours, including the Sacramento Delta and San Joaquin River. Examples illustrate the utility of in situ optical sensors for studies over short-duration events of days to weeks (diurnal cycles, tidal cycles, storm events and snowmelt periods) as well as longer-term continuous monitoring for months to years. We also highlight the application of in situ optical measurements as proxies for constituents that are significantly more difficult and expensive to measure at high frequencies (e.g. methylmercury, trihalomethanes, harmful algal blooms). Relatively simple absorbance and fluorescence measurements made in situ could be incorporated into short and long-term ecological research and monitoring programs, resulting in advanced understanding of sources that contribute to water quality improvements or degradation, contaminant and carbon cycling, the occurrence and persistence of harmful algal blooms.

Bergamaschi, B. A., K. M. Kuivila, et al. (2001). "Pesticides associated with suspended sediments entering San Francisco Bay following the first major storm of Water Year 1996." Estuaries 24: 368-380.

Estuaries receive large quantities of suspended sediments following the first major storm of the water year. The first-flush events transport the majority of suspended sediments in any given year, and because of their relative freshness in the hydrologic system, these sediments may carry a significant amount of the sediment-associated pesticide load transported into estuaries. To characterize sediment-associated pesticides during a first-flush event, water and suspended sediment samples were collected at the head of the San Francisco Bay during the peak in suspended sediment concentration that followed the first major storm of the 1996 hydrologic year. Samples were analyzed for a variety of parameters as well as 19 pesticides and degradation products that span a wide range of hydrophobicity. Tidal mixing at the head of the estuary mixed relatively fresh suspended sediment transported down the rivers with suspended sediments in estuary waters. Segregation of the samples into groups with similar degrees of mixing between river and estuary water revealed that transport of suspended sediments from the Sacramento-San Joaquin drainage basin strongly influenced the concentration and distribution of sediment-associated pesticides entering the San Francisco Bay. The less-mixed suspended sediment contained a different distribution of pesticides than the sediments exposed to greater mixing. Temporal trends were evident in pesticide content after samples were segregated according to mixing history. These results indicate sampling strategies that collect at a low frequency or do not compare samples with similar mixing histories will not elucidate basin processes. Despite the considerable influence of mixing, a large number of pesticides were found associated with the suspended sediments. Few pesticides were found in the concurrent water samples and in concentrations much lower than predicted from equilibrium partitioning between the aqueous and sedimentary phases. The observed sediment-associated pesticide concentrations may reflect disequilibria between sedimentary and aqueous phases resulting from long equilibration times at locations where pesticides were applied, and relatively short transit times over which re-equilibration may occur.

Bernstein, B. B., B. E. Thompson, et al. (1993). "A COMBINED SCIENCE AND MANAGEMENT FRAMEWORK FOR DEVELOPING REGIONAL MONITORING OBJECTIVES." Coastal Management 21(3): 185-195.

Designing environmental monitoring programs to deal with widespread, subtle, and/or cumulative impacts on a regional basis is challenging. It requires a shift away from focusing primarily on individual point sources to a more regional perspective. It also necessitates involving scientists and managers together in a cooperative effort to establish priorities and articulate clear objectives. In our view, this objective-setting task is neither a strictly scientific nor a strictly management activity. It depends on effective communication between scientists and managers but is confounded by differing perspectives, value systems, and behaviors. We present a conceptual framework to assist managers and scientists in this process. This is intended to structure such communication by helping to create a context that permits fruitful give-and-take between the two groups. We then describe a six-part model for specifying the key elements of regional monitoring objectives.

Bessinger, B., T. Cooke, et al. (2006). "A kinetic model of copper cycling in San

Francisco Bay." San Francisco Estuary and Watershed Science 4(1): [np].
A two-dimensional, depth-averaged kinetic model of copper cycling was developed for the San Francisco Bay estuary. Adsorption and desorption reaction rate constants were determined from experimental sorption experiments. To calibrate the model, processes related to aqueous speciation were included. The model was used to predict spatial and seasonal trends in the adsorption and desorption of copper. Model predictions show that copper is continually being re-partitioned between sediment and water. Re-partitioning is prevalent near tributary and anthropogenic sources. It also occurs between segments of the bay, in response to differences in salinity and the availability of organic ligands dissolved in the water. In areas of restricted circulation such as the South Bay, copper adsorbed onto settling particles during wet season storm events acts as a source to the water column during the dry season. The relative contribution of resuspended benthic sediment to dissolved copper concentrations is highly variable in the bay. In the North Bay, dissolved copper is principally introduced from the San Joaquin-Sacramento Delta. In the South and lower South bays, desorption from sediment during the dry season may contribute as much as 20% of the total mass input of dissolved copper. Improvement of water quality can be achieved by reducing loads; however, changes are predicted to take years.

Bigham, K., and S. Foss (2010). San Francisco Bay survey of non-indigenous aquatic species. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The Office of Spill Prevention and Response’s (OSPR) Marine Invasive Species Program is an effort to control the introduction of non-native species into California’s coastal waters. The initial phase involved both field collections and a literature review which resulted in creation of the California Aquatic Non-native Organism Database (CANOD) that includes information on all known non-indigenous species in the marine and estuarine waters of the state. CANOD can be found on the internet at http://www.dfg.ca.gov/ospr. In 2005, we conducted field surveys in San Francisco Bay and are re-sampling the same site in 2010. At each sampling site, multiple habitats were surveyed, including a variety of natural habitat types, such as rocky points, sandy beaches and muddy soft bottom, as well as submerged and floating man-made structures. Species were characterized as non-native, cryptogenic (not enough information to unambiguously determine if they are introduced or native) or unresolved (not identified to species level). Survey results that will be presented will include: 1) the total number of species (or taxa) identified as non-native, native, cryptogenic, and unresolved; 2) a comparison of species found in our survey to those found in past surveys; 3) geographical distribution of non-native species; 4) distribution of non-natives by habitat type; and 5) the most common potential pathways of introduction. We will discuss ongoing surveys, research, and analyses of marine aquatic non-native species in California conducted or sponsored by OSPR’s Marine Invasive Species Program.

Black, M. (1994). "Recounting a century of failed fishery policy toward California's Sacramento River salmon and steelhead." Conservation Biology: the journal of the Society for Conservation Biology 8(3): 892-894.

Black, M. (1995). "Tragic remedies: A century of failed fishery policy on California's Sacramento River." Pacific Historical Review LXIV 1: 37-70.

Black, M. (2001). Shasta salmon salvage efforts: Coleman National Fish Hatchery on Battle Creek, 1895-1992. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 177-268.

Blair, G., and B. Mitchell (2010). Evaluating consequences of unscreened diversions on population performance of Butte Creek spring-run Chinook salmon. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
At present there are more than 3,000 unscreened water diversions in the Central Valley of California. The enormous expense to screen all of these diversions because of a perceived threat to ESA-listed salmon viability makes this solution

impractical. An alternative approach is to evaluate priorities for screening based on their consequences to population abundance and productivity. We describe a modeling approach that evaluated 50 small, unscreened pump diversions and three large, unscreened gravity diversions in lower Butte Creek for their effect on Butte Creek spring-run Chinook salmon. This population is the largest self-sustaining natural population of spring-run Chinook in the Central Valley. We modeled the complete life history of Butte Creek spring-run Chinook under a variety of water year types and screening alternatives. The model incorporates an assessment of fish entrainment losses at individual diversions based on several physical, operational, and biological factors affecting entrainment risk. Also included in the model were environmental attributes affecting Chinook survival throughout their freshwater residence (juveniles and adults). Monthly entrainment losses at individual diversions ranged from less than 0.1% for small pumps to 4.6% for gravity diversions. Potential entrainment losses were highest in the spring of dry and critically dry years because of increased irrigation demands and temporal overlap in diversion and juvenile emigration seasons. Life history modeling suggests that screening all diversions would increase adult abundance by 3% in wet and average water years and 9-10% in dry and critically dry years. The results supported a recommendation to screen a subset of diversions in combination with an integrated flow management and operations agreement among water users.

Bland, R., and K. Crow (2010). Mating call of the plainfin midshipman as an indicator of stress due to anthropogenic noise and other environmental factors. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The plainfin midshipman (Porichthys notatus) is a common finfish in the Eastern North Pacific. Parental males move to estuaries to form mating aggregations to attract females with low-frequency, long-duration acoustic calling produced by rubbing specialized muscles against the swimbladder. We have analyzed acoustic recordings from a hydrophone deployed from the Romberg Tiburon Center research pier in the north San Francisco Bay. Strong signals from singing midshipman are detected during summer months, and sound from passing ships is easily identified. Since the frequency band of ship sound overlaps that of midshipman singing, we propose to determine if masking of singing by ship sound alters midshipman mating behavior. We have studied the intensity, frequency and other features of this humming to determine possible relationships to environmental factors such as water temperature, chemical contaminants in the water, and anthropogenic underwater sound. We find that the diel pattern of midshipman humming is approximately complimentary to the diel distribution of shipping noise, with the midshipmen humming principally at night when shipping traffic is at a minimum. This results indicate that the night-time humming of the midshipman may be a response to the presence of shipping noise during the day, which masks the humming and makes mating more difficult. It may be possible to use this behavioral response to measure the loss of time for mating or other behavioral metrics as a function of the level of shipping traffic. These metrics can be used in management of shipping noise. In addition, we have observed a sharp increase in humming in response to heavy rainfall, which may be due to the presence of chemicals in runoff. Understanding these issues surrounding the survival of native species will help to preserve biodiversity in the Bay-Delta estuary.

Blankenship, S. M., D. Hedgecock, and B. P. May (2002). "Evolution of a perfect simple-sequence-repeat locus in the context of its flanking sequence." Molecular Biology and Evolution 19(11): 9.

Microsatellites, which have rapidly become the preferred markers in population genetics, reliably assign individual chinook salmon to the winter, fall, late-fall, or spring chinook runs in the Sacramento River in California’s Central Valley (Banks et al. 2000. Can. J. Fish. Aquat. Sci. 57:915–927). A substantial proportion of this discriminatory power comes from Ots-2, a simple CA repeat, which is expected to evolve rapidly under the stepwise mutation model. We have sequenced a 300-bp region around this locus and typed 668 microsatellite-flanking sequence haplotypes to explore further the basis of this microsatellite divergence. Three sites of nucleotide polymorphism in the Ots-2 flanking sequence define five haplotypes that are shared by the Californian and Canadian populations. The Ots-2 microsatellite alleles are nonrandomly distributed among these five haplotypes in a pattern of gametic disequilibrium that is also shared among populations. Divergence between the winter run and other Central Valley stocks appears to be caused by a combination of surprisingly static evolution at Ots-2 within a context of more rapidly changing haplotype frequencies.

Blaser, S., F. Wilkerson, and A. Parker (2010). Effect of Diuron and Imazapyr herbicides on phytoplankton in the San Francisco Estuary. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Herbicides have the potential to negatively affect marine and aquatic ecosystems as they are mobilized through precipitation and other factors from the land into the watershed. Diuron is an herbicide of concern in the northern San Francisco Estuary (SFE) because it is heavily used for both agricultural and urban land, is toxic, and persistent in the environment. Despite its known presence in the SFE, little is known about its potential impact on phytoplankton communities. Another herbicide in use in the SFE is Imazapyr, which is applied to manage invasive plants. Imazapyr is not currently monitored in the SFE, nor is much understood about potential unintended consequences of Imazapyr to phytoplankton. Experiments were conducted to empirically determine the impact of increasing concentrations of Diuron or Imazapyr on primary production, nitrogen uptake, and community composition of natural phytoplankton assemblages collected in the SFE. Results show that primary production was reduced with Diuron concentrations as low as 1 µg/L; these concentrations fall within the range of Diuron concentrations that have been previously reported for the northern SFE and Delta. Phytoplankton nitrogen uptake was reduced much the same as carbon uptake. Increasing concentrations of Imazapyr resulted in decreased production during chronic (long term) exposure at high Imazapyr concentrations (5 mg/L) with limited impact during acute (immediate) tests. These findings provide evidence that herbicides may reduce primary production and shape phytoplankton communities in the food-limited SFE. For future ecosystem sustainability, the impact of land-applied herbicides on water column food webs needs to be considered.

Blum, M. J., K. Jun Bando, et al. (2007). "Geographic structure, genetic diversity and source tracking of Spartina alterniflora." Journal of Biogeography 34(12): 2055-2069.

Aim To examine the distribution and structure of genetic variation among native Spartina alterniflora and to characterize the evolutionary mechanisms underlying the success of non-native S. alterniflora. Location Intertidal marshes along the Atlantic, Gulf and Pacific coasts of North America. Methods amova, parsimony analysis, haplotype networks of chloroplast DNA (cpDNA) sequences, neighbour-joining analysis, Bayesian analysis of population structure, and individual assignment testing were used. Results Low levels of gene flow and geographic patterns of genetic variation were found among native S. alterniflora from the Atlantic and Gulf coasts of North America. The distribution of cpDNA haplotypes indicates that Atlantic coast S. alterniflora are subdivided into 'northern' and 'southern' groups. Variation observed at microsatellite loci further suggests that mid-Atlantic S. alterniflora are differentiated from S. alterniflora found in southern Atlantic and New England coastal marshes. Comparisons between native populations on the Atlantic and Gulf coasts and non-native Pacific coast populations substantiate prior studies demonstrating reciprocal interspecific hybridization in San Francisco Bay. Our results corroborate historical evidence that S. alterniflora was introduced into Willapa Bay from multiple source populations. However, we found that some Willapa Bay S. alterniflora are genetically divergent from putative sources, probably as a result of admixture following secondary contact among previously allopatric native populations. We further recovered evidence in support of models suggesting that S. alterniflora has secondarily spread within Washington State, from Willapa Bay to Grays Harbor. Main conclusions Underlying genetic structure has often been cited as a factor contributing to ecological variation of native S. alterniflora. Patterns of genetic structure within native S. alterniflora may be the result of environmental differences among biogeographical provinces, of migration barriers, or of responses to historical conditions. Interactions among these factors, rather than one single factor, may best explain the distribution of genetic variation among native S. alterniflora. Comprehensive genetic comparisons of native and introduced populations can illustrate how biological invasions may result from dramatically different underlying factors - some of which might otherwise go unrecognized. Demonstrating that invasions can result from several independent or interacting mechanisms is important for improving risk assessment and future forecasting. Further research on S. alterniflora not only may clarify what forces structure native populations, but also may improve the management of non-native populations by enabling post-introduction genetic changes and the rapid evolution of life-history traits to be more successfully exploited.

Bochdansky, A. B. and S. M. Bollens (2004). "Relevant scales in zooplankton ecology: Distribution, feeding, and reproduction of the copepod <i>Acartia hudsonica</i> in response to thin layers of the diatom <i>Skeletonema costatum</i>." Limnology and Oceanography 49(3): 625-636.

We investigated the interaction of the copepod Acartia hudsonica in relation to thin layers of the diatom Skeletonema costatum. Thin layers have recently received much attention, since they are common and persistent features in the water column, often overlooked by traditional sampling methods. Their frequent abundance in coastal oceans and the high biomass associated with them has led to the assumption that they are important grazing sites of calanoid copepods. We employed 2-m tall tower tanks that allowed us to simulate thin layers. Three variables representative of three time scales were considered: the distribution of copepods in the tanks (time scale of minutes), fecal pellet production as a proxy for ingestion rate (time scale of hours), and egg production rate (time scale of >12 h). A. hudsonica responded significantly but very little to the thin layers in terms of their distribution. Given a choice, there was a slightly higher tendency to swim through a patch of diatoms than to swim around it. Fecal pellet production was slightly lower in the thin-layer treatments than in the homogeneous controls. Egg production was not influenced by differential distribution of diatoms in the tanks, which indicated that the copepods dealt equally well with patchy food as when the same numbers of cells were available in a homogeneous distribution. Time series experiments showed that ingested carbon is integrated over time scales of >12 h. Therefore, small scale fluctuations of food in space and time do not necessarily translate into small-scale fluctuations in reproductive output.

Bochdansky, A. B. and S. M. Bollens (2009). "Thin layer formation during runaway stratification in the tidally dynamic San Francisco Estuary." Journal of Plankton Research 31(11): 1385-1390.

During the course of a year, we repeatedly collected high-resolution vertical fluorometer data timed to coincide with a specific state during the tidal cycle. The time (end of the ebb during neap tide) and the location (a deep channel half-way between the Golden Gate and the point of tidally averaged bottom salinity of 2 psu) were chosen with the goal to observe runaway stratification. We consistently found at least one pronounced chlorophyll peak in the water column; however, the vertical location of these peaks varied within three types including surface, bottom and subsurface maxima. Our results showed that heterogeneity of chlorophyll in the water column and thin layer formation do occur in systems that are characterized by high tidal flow speeds thus resulting in patchy prey fields for zooplankton that migrate in tidal cycles through the water column. Using these chlorophyll profiles, approximate calculations suggested that only during the spring phytoplankton bloom did all layers of the water column provide sufficient food for maximum egg production of the San Francisco Estuary copepod Acartia sp.

Bodensteiner, S., S. LaMothe, H. Pleiss, S. Leskie, and I. Bruce (2010). Environmental impacts and regulatory implications of the apparent expulsion of the hydraulic mining era pulse of mercury laden sediment from San Francisco Bay. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Over several decades, a significant reduction in the sediment load entering San Francisco Bay from the Delta and its major river tributaries has spurred an increase in the resuspension of the Bay’s erodible sediment pool allowing suspended sediment concentrations to maintain equilibrium. Recently published data (NOAA 2009) suggest that the erodible sediment pool, consisting primarily of shoaled sediments from Gold Rush era hydraullic mining, may have been essentially depleted. If ambient

mercury concentrations in Bay sediments have been reduced with the depletion of mining related sediments, how will policy measures aimed at reducing levels of mercury in San Fracisco Bay (i.e. mercury TMDL) be impacted?   Recent deepening the Oakland Harbor navigation channels to pre-industrial sediment strata, make this location an ideal for assessing the trend in mercury concentrations in newly shoaled sediments in San Francisco Bay. Sediment samples from the Oakland Harbor were collected prior to maintenance dredging every year since the deepening project was completed and analyzed for mercury. Results were compared to historic levels documented for Oakland Harbor and other regions within the Bay.   The results of this investigation show that mercury present sediments newly accreted in Oalkand Harbor every year since the navigation channel was deepened are consistent with pre-industrial, background concentrations (~0.23 mg/kg). Conclusions: Under the Clean Water Act's Section 303d, the San Francisco Bay was deemed impaired for mercury, and a Total Maximum Daily Load (TMDL) for this contaminant was developed and amended to the San Francisco Bay Regional Water Quality Control Board's Water Quality Control Plan. A significant reduction in ambient San Francisco Bay mercury sediment concentrations associated with the apparent dramatic depletion in mining related sediments may imply that a substanitial reduction in the total Bay Area mercury load, and warrant a modification to the mercury TMDL implementation plan. This is especially true for Bay Area dredge permit applicants because the TMDL currently prohibits discharge of dredged material to the Bay's authorized aquatic disposal sites unless the material exhibits concentrations lower than the current ambient sediment mecury concentration (0.53 mg/kg).

Bollens, S. M., J. R. Cordell, et al. (2002). "Zooplankton invasions: a brief review, plus two case studies from the Northeast Pacific Ocean." Hydrobiologia 480: 1-3.
        Invasions of aquatic habitats by non-indigenous species (NIS), including zooplankton, are occurring at an alarming rate and are causing global concern. Although hundreds of such invasions have now been documented, surprisingly little is known about the basic biology and ecology of these invaders in their new habitats. Here we provide an overview of the published literature on NIS zooplankton, separated by life history (holoplankton vs. meroplankton), habitat (marine, estuarine, freshwater), and biological level of organization or topic (e.g. distribution and range extension, physiology, behavior, feeding, community impacts, ecosystem dynamics, etc). Amongst the many findings generated by our literature search, perhaps the most striking is the paucity of studies on community and ecosystem level impacts of NIS zooplankton, especially in marine and estuarine systems. We also present some results from two ongoing studies of invasive zooplankton in the northeast Pacific Ocean - Pseudodiaptomus inopinus in Washington and Oregon coastal estuaries, and Tortanus dextrilobatus in San Francisco Bay. Both of these Asian copepods have recently expanded their range and can at times be extremely abundant (10 super(3) m super(-3)). We also examine some aspects of the trophic (predator-prey) ecology of these two invasive copepods, and find that they are likely to be important in the flow of material and energy in the systems in which they now pervade, although their impacts at the ecosystem level remain to be quantified. Finally, the findings of both our literature search and our two case studies of invasive zooplankton lead us to make several recommendations for future research.

Bollens, S. M. and A. M. Sanders (2004). Ecology of Larval Pacific Herring in the San Francisco Estuary: Seasonal and Interannual Abundance, Distribution, Diet, and Condition. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 15-35.
        Pacific herring Clupea pallasi is a commercially and ecologically important fish with a sizable stock that spawns and spends its early life history in the San Francisco Estuary (SFE). Yet very little is known about the basic ecology of larval Pacific herring in the SFE. We undertook a 3-year field study (1999-2002), focused on winter and spring collections in two regions of the SFE (the Central and San Pablo bays), to address three objectives: (1) determine seasonal abundance patterns of larval Pacific herring in the two bays, (2) examine the diet of larval Pacific herring, and (3) evaluate the condition of larval Pacific herring in the two bays.

Pacific herring were a conspicuous component of the winter larval fish assemblage in both the San Pablo and Central bays, comprising a maximum of 22.5% and 5.5% of total abundance, respectively. Larval Pacific herring abundance peaked in February or March of each year, reaching a maximum density of 2.53/m super(3) (San Pablo) and 0.52/m super(3) (Central Bay). Length frequency distributions suggested that at least 2-3 cohorts were produced each year, with some evidence that larvae were slightly larger in San Pablo Bay. Larval Pacific herring fed on a broad range of prey types, including tintinnids, copepodids, copepod nauplii, diatoms, and gastropod veligers. The unusually high proportion of tintinnids in the diet (87% by number in March 2001) suggests an important protozoan-metazoan linkage. Condition of larvae was assessed by analyses of covariance of a "growth sensitive" variable (i.e., body weight, anal body depth, or pectoral body depth) regressed against a "growth insensitive" variable (i.e., standard length). These results showed marked differences between the bays: in Central Bay, early (small) larvae exhibited better condition, but within San Pablo Bay, larvae exhibited a greater rate of improved condition with increasing age (size). This suggests the possibility of important differences in the Central and San Pablo bays as larval Pacific herring nursery grounds. Several areas of future research on the ecology of larval Pacific herring in SFE are recommended (e.g., coupling between horizontal and vertical distributions and advective flow fields, predation, and feeding dynamics on protozoan versus metazoan prey).

Bombardelli, F., J. Kohne, S. Reddy, D. Behrens, and M. Gowdy (2010). Comparison of models for predicting flow and water quality in the Sacramento-San Joaquin Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The social and economic importance of the Sacramento-San Joaquin Delta has led to the development and application of several numerical models to predict hydrodynamic and water quality conditions. Yet future challenges to the Delta will require even more demanding applications of these models to simulate climate change, water management, habitat, island failures, and land development conditions. This work presents a rigorous and independent framework for the analysis of several Delta-specific models developed by Resource Management Associates (RMA) and the Department of Water Resources (DWR). This presentation starts with a thorough analysis of the models from the theoretical and numerical points of view. Subsequently, it includes a scenario-driven comparison of each model to historical data and investigates model accuracy and sensitivity to varying levels of export pumping and DICU values, each within extreme dry and wet water years.

Bombardelli, F., J. Anderson, E. Atlejevich, and K. Zamani (2010). Technical details of the development of a sediment-transport module for DSM2. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

This presentation describes the development of a one-dimensional Sediment and Transport Module (STM) for the Delta Simulation Model 2. STM is a general transport model for conservative and non-conservative constituents with special focus on sediment transport. The module includes cohesive and non-cohesive sediment transport in tidal channel networks. Both suspended sediment and bed load are simulated in the module. STM uses a second order accurate, finite volume numerical solution. To verify that components of the model are coded properly, a companion testing code has been developed.

Bond, R., M. Partyka, and E.R. Atwill (2010). The occurrence of indicator bacteria and waterborne zoonotic pathogens in the California Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

A two year intensive study was conducted from June 2006 through December 2008 on a section of the California Delta. This study addressed the use of bacterial indicators, E. coli and Enterococcus, to identify priority bacterial pathogens potentially shed by livestock populations located throughout the Delta: Salmonella, Shiga like toxin producing E. coli (SLTEC), and Campylobacter. Many of these pathogens can be transmitted to humans, other domestic animals, and wildlife through the waterborne route of transmission. We identified 88 monitoring sites throughout

the sloughs and waterways of the eastern and northwestern Delta, and surveilled them monthly for bacterial source identification, pathogen load estimations, and standard water quality metrics. A total of 1740 water samples were taken during three distinct seasons (Rainfall, Nov-Mar; Snowmelt, Apr-Jun; Dry, Jul-Oct) over the course of the study period. The prevalence of indicators appears to be seasonally dependent with a higher percentage of samples exceeding the single sample maximum (SSM) for both E. coli (235 CFU/100 ml) and Enterococcus (61 CFU/100 ml) in the Rainfall season and the Dry season than the Snowmelt season. The occurrence of pathogens was low to moderate; Salmonella (4.7%, n=1740), Campylobacter (14.99%, n=1501), and SLTEC (1.24%, n=1366). The average bacterial counts of Salmonella (MPN/100 ml) and Campylobacter (CFU/100 ml) were not significantly higher in samples that exceeded the (SSM) for either indicator E. coli (p=0.44, p=0.25 respectively) or Enterococcus (p=0.39, p=0.08 respectively). Sampling season proved to be a strong predictor for the occurrence of SLTEC when coupled with exceedance of the Enteroccocus SSM (p=0.014). Rainfall driven seasonal variations appear to influence the occurrence of both indicator bacteria and bacterial pathogens. While further sampling may prove beneficial to Delta stakeholders, this study is one of the most comprehensive examinations of microbial water quality in the California Delta to date.

Booker, K., and J. Martini-Lamb (2010). North Bay Water Reuse Program. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Problem Statement: The North San Pablo Bay region has very limited surface and groundwater supplies. Urban, agricultural and environmental demands exceed the region’s ability to provide a reliable, sustainable and economical water supply. Water managers and elected officials recognize the contribution recycled water can make in helping to address water supply reliability. Approach: Since the regional North Bay Water Recycling Program (NBWRP) was concieved, over 10-years ago, the North Bay Water Reuse Authority (NBWRA) has made considerable headway in its implementation of the Program’s vision. NBWRA has launched and completed essential multi-phase technical and economic feasibility studies, conducted broad stakeholder outreach efforts targeting both agencies and potential users of recycled water and forged key partnerships to obtain and share funding resources. The NBWRP goal is to determine how the region’s recycled water supply can provide as many benefits as possible to all stakeholders – urban, agriculture, and environmental. Results: In partnership with the Bureau of Reclamation, studies have been completed to establish the feasibility of a comprehensive regional program for recycled water. The NBWRP is expanding the existing use of recycled water to users in areas which are severely impacted by groundwater overdraft, to offset potable water used for urban an agricultural irrigation, and to provide fresh water for bittern pond restoration at the Napa-Sonoma Salt Marsh. Conclusions: Although the North San Pablo Bay region is not served by federal or state water projects, the NBWRP demonstrates how a long-term sustainable supply of recycled water can be developed by partnering with federal and state agencies. The NBWRP is a model for maximizing the benefits of limited water resources in the West. This comprehensive regional program provides a sound approach towards meeting local, state, and federal water management objectives and regulatory requirements and helps put recycled water to its broadest and most beneficial use.

Borgnis, E., V. T. Parker, J. Callaway, and L. Schile (2010). Below-ground biomass dynamics across the San Francisco Bay-Delta: Organic and mineral matter contributions to tidal wetland accretion. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Organic matter (OM) accumulation is a critical factor affecting vertical rates of sediment accretion in tidal wetlands. Accretion will determine the ability of wetlands to maintain elevation and persist in the face of sea-level rise (SLR). Global climate change (GCC) is predicted to increase rates of SLR and shift salinity regimes, resulting in uncertainty for the future of San Francisco Bay-Delta wetlands. Recent models based only on allochthonous mineral sediment deposition indicate that rates of SLR may exceed wetland accretion rates. Our study focuses on measuring autochthonous OM contributions to vertical accretion and the effect of salinity and elevation on OM accumulation in six tidal wetlands spanning the estuarine salinity gradient of the SF Bay-Delta. We are using data on above- and below-ground productivity, decomposition and soil chemistry from shallow cores to model accretion dynamics in conjunction with existing data from SETs, marker horizons, and dated sediment cores. Preliminary results indicate that strong trends in processes across the salinity gradient have substantial implications for GCC impacts on Bay-Delta wetlands. At saline sites, sediment accretion averages 3 mm/yr but shallow compaction reduces elevation gains to 1 mm/yr. Decomposition rates in saline sites are double rates in freshwater sites, while productivity is 10X greater in freshwater sites leading to higher observed soil OM content. Interestingly, the peak in above-ground biomass occurs in the fresh wetland, while the peak in below-ground biomass occurs at the brackish wetland. These results will aid in predicting impacts of GCC on the long-term stability of tidal wetlands.

Botsford, L. W., and J.G. Brittnacher (1996). "Viability of Sacramento River winter-run chinook salmon." Conservation Biology: the journal of the Society for Conservation Biology 12: 15.
The winter run of chinook salmon (Oncorhynchus tshawytscha) on the Sacramento River in California (U.S.A.) was the first Pacific salmon stock to be listed under the U.S. Endangered Species Act. We describe some of the characteristics of Pacific salmon populations that require special consideration in viability analysis while developing a model specific to the Sacramento River winter run of chinook salmon. Their anadromous, semelparous life history leads to a special definition of quasi-extinction. Random variability occurs primarily in spawning or early life and is reflected in the cohort replacement rate, the number of future spawners produced by each spawner, a measure consistent with the common practice of characterizing salmon population dynamics in terms of stock-recruitment relationships. We determine the distribution of cohort replacement rates from spawning abundance data and life history information. We then show through simulations that (1) replacing this distribution with a lognormal distribution with the same mean and variance has a negligible effect on extinction rates, but that (2) approximating an indeterminate semelparous life history using a determinate semelparous life history leads to inaccurate estimates of extinction rate. We derive delisting criteria that directly assess the effects of habitat improvement by explicitly including population growth rate (geometric mean cohort replacement rate > 1.0) in addition to abundance (> 10,000 female spawners). These delisting criteria allow for the uncertainty due to limited accuracy in measuring spawner abundance and the finite number of samples used to estimate population growth rate (estimates must be based on at least 13 years of data, assuming spawner abundance is measured with < 25% error). Because the probability of extinction will generally be very sensitive to the uncertainty involved in meeting delisting criteria, we recommend that similar uncertainty be accounted for in future recovery criteria for all endangered species.

Botsford, L. W., R. D. J. Methot, et al. (1982). "Cyclic covariaton in the California king salmon, Oncorhynchus tshawytscha, silver salmon, O. kisutch, and dungeness crab, Cancer magister, fisheries." Fishery Bulletin 80: 791-801.

Bouley, P. and W. J. Kimmerer (2006). "Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary." Marine Ecology Progress Series 324: 219-228.
The cyclopoid copepod Limnoithona tetraspina (Oithonidae) was introduced into the San Francisco Estuary (SFE) in 1993 and within a year became the most abundant copepod in the low-salinity zone. L. tetraspina makes up similar to 95% (median) of the total adult copepods in the low-salinity zone, and the biomass of adults is similar to that of 2 larger co-occurring calanoids, Pseudodiaptomus forbesi and Eurytemora affinis. The main goal of our research was to understand which food resources L. tetraspina uses in the low-salinity region of the SFE. Incubation experiments using natural water revealed feeding by L. tetraspina on mixotrophic and heterotrophic aloricate ciliates, but rarely on loricate tintinnids or diatoms. The co-occurring calanoids consumed similar prey, but also readily consumed diatoms. Capture and consumption of Strombidium spp. by L. tetraspina was confirmed visually, and experiments using cultured prey also showed that these copepods fed on motile phytoplankton but not on diatoms. Estimated grazing rates were low (median 2.3, range 0.6 to 8.3% body weight d(-1)); although these rates may

be underestimates because of high concentrations of copepods in experimental containers, they are consistent with low specific egg production of females (0.3 +/- 0.2% body weight d(-1)). Low selectivity of one fish species for L. tetraspina suggests that this copepod may not be an important food resource for visually-selective fishes in the SFE. The low abundance of filter-feeding predators in this region of the estuary may be responsible for the high abundance of this cyclopoid copepod, despite its low potential population growth rate.

Bowman, T. E. and J. J. Orsi (1992). "Deltamysis holmquistae, a new genus and species of Mysidacea from the Sacramento-San Joaquin Estuary of California." Proceedings of the Biological Society of Washington 105: 733-742.

Boyd, T. J. and C. L. Osburn (2004). "Changes in CDOM fluorescence from allochthonous and autochthonous sources during tidal mixing and bacterial degradation in two coastal estuaries." Marine Chemistry 89(1-4): 189-210.
Chromophoric dissolved organic matter (CDOM) was collected and concentrated using 1 kDa cutoff tangential flow filtration (TFF) from marine (similar to 33 salinity), mid-estuarine (similar to 15 salinity), and freshwater (1 salinity) portions of the Chesapeake and San Francisco Bays. Natural bacterioplankton were also collected during the same transects on 0.22- mu m pore size filters. TFF permeates from freshwater, mid-estuarine and marine stations were used to create a series of salinity samples ranging from 0 to 33 by increments of 3. Freshwater CDOM was added in the same proportion to each salinity sample to determine changes in spectral signals during simulated estuarine mixing. A series of incubations was conducted in which concentrated CDOM was added to TFF permeates (1 kDa, low fluorescence) in a nine-membered matrix such that each station's CDOM was added to each station's TFF permeate. Each incubation was then inoculated with a filter from its respective collection location. Subsamples from bacterial incubations were collected at various times and analyzed by high resolution three-dimensional fluorescence excitation-emission spectroscopy (EEMs) to determine if changes in ionic strength encountered during estuarine mixing affect the bioavailability and optical properties of CDOM. Five EEMs peaks were identified for each mixing experiment and microbial subsample; Exmax: 330-350 nm/ Emmax: 420-480 nm, Exmax: 250-260 nm/ Emmax: 380-480 nm, Exmax: 310-320 nm/ Emmax: 380-420 nm, Exmax: 270-280 nm/ Emmax: 300-320 nm, and Exmax: 270-280 nm/ Emmax: 320-350 nm. These peak ratios were monitored over the time course of the experiment. Changes in several spectral properties during the simulated estuarine mixing were observed indicating CDOM conformational changes as it moves through the estuary. We hypothesized these changes may impact the biodegradability of CDOM as it moves from upland sources to the coastal ocean. Changes in DOC concentration during incubation indicated that allochthonous CDOM was a more utilizable substrate for estuarine and marine bacteria. There were also differences in peak ratios observed during incubation with allochthonous and autochthonous CDOM. There were Emmax peak shifts dependent on the source of CDOM and bacteria, with more red shifting (toward higher wavelengths) in upper reaches of the estuary and more blue-shifting at the oceanic end-member. We conclude that bacterial degradation of specific components of autochthonous and allochthonous CDOM may impact the spectral characteristics observed throughout an estuary and that CDOM optical properties are partially a function of the CDOM's origin and mixing history.

Boydstun, L. B. (1994). "Analysis of two mark-recapture methods to estimate the fall chinook salmon, Oncorhynchus tshawytscha, run into Bogus Creek, upper Klamath River, California." California Fish and Game 80: 1-3.

Boydstun, L. B. (2001). Ocean salmon fishery management. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 183-196.
California ocean salmon fisheries are managed by the Pacific Fishery Management Council (Council) under the federal Magnuson Stevens Fishery Conservation and Management Act. This chapter describes the ocean fisheries impacting California Central Valley (CV) chinook stocks, the federal regulatory process that is followed in managing these ocean fisheries, and discusses alternative management measures for protecting valuable natural resources. The CV supports fall, late-fall, winter, and

spring chinook runs. The Council has adopted a spawning escapement goal for the fall run, while a federal rebuilding plan is used to regulate the fisheries to protect the winter run, an endangered species. The winter run plan is also protective of CV spring run, a threatened species. Some potential alternative management strategies include (1) a revised escapement goal for the Sacramento fall run, (2) a separate escapement goal for the spring run, (3) an escapement goal for the San Joaquin fall run, and (4) a selective ocean fishery for marked hatchery fish. The CV salmon management program is lacking in two areas: (1) river return estimates for codedwire- tagged fish releases and (2) inconsistent tagging of hatchery fish releases, precluding estimation of hatchery fish contributions. I conclude that a comprehensive fishery management program should be implemented for CV chinook salmon under the Central Valley Project Improvement Act and that the Klamath Fishery Management Council be used as a model for developing such a program.

Brand, A., S. Gladding, J.R. Lacy, and M.T. Stacey (2010). Model based interpretation of sediment concentration and vertical flux measurements in the shoals of South San Francisco Bay. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Our study focused on the driving factors of sediment resuspension and settling dynamics in the shoals of South San Francisco Bay. We deployed an array of stations in spring and fall 2009 at a shallow field site (2.19-2.59 MLLW) to measure horizontal and vertical gradients of turbidity together with fluid flow, turbulence, and pressure across the shoal-channel transition. Flow velocities, Reynolds stress, wave properties, sediment concentration and turbulent sediment fluxes were measured using ADVs. We developed a simple 1-D dispersion-settling model to interpret the observed sediment concentrations and fluxes. We assumed the existence of two sediment fractions with differing settling behavior. Sediment resuspension into the water column was described as a linear function of the observed sediment flux. Our model study showed that the observed concentrations were best described by a fast settling fraction with a constant settling velocity ws of 0.003 ms-1 attributed to coarse particles and a slowly settling fraction with a concentration dependent settling velocity ws=k*CSed with k = 8*10-6 m4 s-1g-1attributed to fine particles, suggesting a coagulation mechanism for the settling of the latter fraction. Modeled sediment concentration profiles showed that the fine sediment fraction can contribute over 70% of the sediment mass. Still, steeper gradients in the profiles of the coarse particles show that these particles are the main contributors to the measured sediment flux. Understanding the sediment transport in the South San Francisco Bay is of crucial importance for the prediction of contaminant and nutrient dynamics as well as predicting the formation and erosion of wetlands and intertidal mudflats. Our study highlights the importance of differing particle fractions in the sediment dynamics of the Bay, especially since these fractions differ in residence time in the water column. The presented results also provide a good starting point for a fully coupled sediment bed-water column model.

Brand, L. A., J.Y. Takekawa, J. Bluso-Demers, J. Shinn, N. Athearn, C. Robinson-Nelsen, and C. Strong (2010). Effects of management on avian populations in the South Bay salt ponds: density changes from 2003-2010. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

A long-term goal for the South Bay Salt Pond Restoration Project (SBSPRP) is to restore a mix of habitats ranging from tidal marsh to open ponds that balance needs of marsh species with migrating waterbird populations. As the SBSPRP enters its first phase, it is important to take stock of the effects of early management efforts on avian populations. We conducted monthly waterbird counts and sampled salinity and dissolved oxygen in three SBSPRP salt pond complexes since 2003 (53 ponds in Alviso, Eden Landing, and Ravenswood), and in two salt production pond complexes since 2005 (22 ponds in Newark and Mowry). We used generalized least-squares regression for clustered data with pond as a random effect to assess temporal trends in average avian densities, salinity, and dissolved oxygen over years, after adjusting for seasons, and as a function of pond complexes and pond management types. Over a common temporal period (2005-2010), small and medium shorebirds and dabbling and diving ducks had higher densities in restored than production ponds but there were no significant ($p < 0.05$) density changes over years. Gulls, terns, fish eating birds and eared grebes had similar or higher densities in production ponds with few trends over time but gulls decreased in restored ponds and eared grebes decreased in production ponds over the time period. Over the longer period in restored ponds (2003-2010), small and medium shorebirds densities were relatively high but decreased in Ravenswood and increased in Eden Landing. Medium shorebirds and dabbling ducks increased in breached ponds. Dabbling and diving ducks had highest densities in Alviso intake ponds; both dabbling duck and fish eater densities increased substantially in Alviso ponds over the study period, perhaps related with increased dissolved oxygen and decreased salinity. Results from this study will help managers assess how changing pond characteristics influence avian populations.

Brander, S. M., and G. Cherr (2010). From otoliths to oocytes: a three-tiered investigation into estrogenic and androgenic effects in a California estuary. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Endocrine disrupting compounds (EDCs) are widespread in the environment and known to impact fish reproduction. A large body of work exists on EDC effects in laboratory species; however, fewer studies have considered resident fish, particularly those found in estuaries. We use Menidia audens, a ubiquitous euryhaline atherinid, as an indicator of EDCs in Suisun Marsh, in which a wide range of contaminants, including emerging EDCs (i.e. pyrethroids), are present. Our three-tiered investigation encompasses the receptor, individual and population levels. First, solid-phase extracts from areas exposed to treated wastewater, urban or ranch run-off produce significant evidence of binding to the nuclear estrogen and androgen receptor in receptor-transfected cell lines. Secondly, immunoanalyses reveal that wild males express choriogenin (egg shell protein); outplanting and bioassays indicate choriogenin levels in marsh-exposed and pyrethroid-exposed fish are greater than controls and endocrine-related gene expression differs between field sites and controls. Lastly, sites exposed to different EDCs exhibited significantly different sex ratios and sex-specific size differences throughout 2009. These results suggest that individual-level effects may scale up to population-level consequences.

Brander, S. M. (2013). Thinking Outside the Box: Assessing Endocrine Disruption in Aquatic Life. Monitoring Water Quality: Pollution Assessment, Analysis and Remediation. S. Ahuja. Amsterdam, Boston, ... Elsevier: 103-147.

Exposures to environmental concentrations of endocrine disrupting compounds (EDCs) are now a known threat to both human and ecological health. A large body of work has established that EDCs can agonize, antagonize or synergize the effects of endogenous hormones, resulting in physiological and behavioral abnormalities in aquatic organisms. Examples of disruption in fishes include altered secondary sexual characteristics and male production of female reproductive proteins. The universe of potential EDCs is expanding as new pesticides and pharmaceuticals constantly enter the marketplace, and the monumental tasks of prioritizing the backlog of compounds to be assessed and reducing their release into the environment remains. In the recent past, the majority of EDC research has focused on reproductive impacts, particularly those caused by estrogenic compounds, or to a lesser extent, androgenic compounds. Attention is now being directed toward impacts inflicted via novel mechanisms and toward impacts on other aspects of the endocrine system. Examples of lesser-known impacts of EDCs on fish include changes in somatic growth and modulation of the immune system. EDCs are known to disrupt pathways mediated by thyroid hormone, glucocorticoids, progestogens, and prostaglandins via receptor-binding, to interfere with cellular signaling cascades, or alter steroidogenesis. The challenge for ecotoxicologists is to determine which end points should be measured in fish in order to most accurately predict impacts at the population and even at the ecosystem level. Furthermore, in addition to assessing risk at multiple biological scales, the effects of complex environmental mixtures, differences in species sensitivity, adaptation to pollution, and the potential for epigenetic change must also be integrated into determinations of “safe” EDC concentrations. Considering the propensity of EDCs to exert effects at low doses and to exhibit nonmonotonic responses, this is a task that will require increased collaboration and ingenuity amongst researchers in the field.

Brander, S. M., I. Werner, et al. (2009). "Toxicity of a dissolved pyrethroid mixture to Hyalella azteca at environmentally relevant concentrations." Environmental Toxicology and Chemistry 28(7): 1493-1499.

Use of pyrethroid pesticides, which are highly toxic to aquatic organisms, has increased substantially over the past decade. In 2006, the pyrethroid pesticides cyfluthrin and permethrin were measured in Sacramento-San Joaquin (SSJ) Delta (CA, USA) water at 5 and 24 ng/L (pptr), respectively. To elucidate any interactions between the two pyrethroids, a 10-d laboratory exposure was performed with 7- to 14-d-old amphipods (Hyalella azteca). Cyfluthrin and permethrin were tested singly and in combination at detected levels and also at half and twice the detected levels, both with and without the addition of 25 ppb of piperonyl butoxide (PBO). Mortality in all treatments was significantly higher than in controls, with the median lethal concentration (LC50) for permethrin with PBO (13.9 ng/L) and the LC50s with and without PBO for cyfluthrin (5.7 and 2.9 ng/L, respectively) at or below levels measured in SSJ Delta water samples. The LC50 for permethrin alone was estimated to be 48.9 ng/L. To evaluate combined toxicity, logistic regression models containing terms for concentrations of cyfluthrin, permethrin, and PBO, as well as models containing all possible combinations of these terms and interactions, were run and compared using Akaike’s information criterion. The most parsimonious set of models indicated slight antagonism between cyfluthrin and permethrin. Results indicate that a dissolved mixture of cyfluthrin and permethrin is toxic at environmentally relevant concentrations in the water column.

Brandes, P. L., and J.S. McLain (2001). Juvenile chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 39-138.

All four races of juvenile Central Valley chinook salmon migrate through and many rear in the Sacramento-San Joaquin Delta and Estuary. Delta residence and migration is considered important in determining adult production, as it is generally believed that density dependent effects are minimal after this life stage. Populations of winter run and spring run are presently listed as endangered and threatened species, while the remaining populations in the Central Valley are candidate species. Actions in the Delta to improve survival are likely important in the recovery of these depressed populations. The tidally influenced freshwater Delta also is an important area for water management in California, as it is where the Central Valley and State Water Project pump large volumes of water to southern California, the San Joaquin Valley and the Bay area. To document the effect of these various water management activities in the Delta on juvenile salmon, monitoring and special studies have been conducted since the early 1970s to the present. Changes in abundance in the Delta and estuary appear related to flow; high flows increase the use of the Delta and San Francisco Bay by fry. Relative survival of fry appears greater in the upper Sacramento River than in the Delta or bay, especially in the wetter years. Survival appears lower in the Central Delta relative to that in the North Delta in drier years for both fry and smolts. Fall-run smolt and late-fall run yearling survival studies have found that diversion into the Central Delta via the Delta Cross Channel or Georgiana Slough reduces survival through the Delta. Experiments in the San Joaquin Delta have shown that survival appears greater for smolts that migrate down the mainstem San Joaquin River rather than through upper Old River. A temporary barrier in upper Old River was tested and found to improve survival for smolts originating in the San Joaquin basin. These specific experiments have identified management actions that could improve juvenile salmon survival through the Delta. In addition, indices of annual survival provide a way to compare survival through the Delta and could be used to assess restoration and management actions. This work demonstrates how long-term scientific studies can be applied to address management and restoration issues.

Brandes, P. L., and M. Banks (2010). Comparison of race using length at date criterion and genetics for catch of juvenile Chinook salmon at Sacramento and Chipps Island in 2007-2008. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

One of the first steps in estimating juvenile abundance of the listed races of Chinook salmon in the Delta is correctly identifying the race of juvenile Chinook caught. The relative abundance of the four races of juvenile Chinook salmon migrating through the Delta cannot be inferred with confidence using length-at-date criterion alone (Johnson et al. 1992). Fin tissue was collected from juvenile Chinook salmon captured in standard trawl sampling conducted at Sacramento and Chipps Island in 2007 and 2008. These tissue samples were then analyzed using DNA microsatellite loci to determine race of individuals in the catch. The number of fish identified as a specific race using the length-at-date criteria was compared to the race identification by DNA for juvenile salmon collected in 2007 and 2008. Results suggest that the catch of winter and spring run is overestimated using the size criterion, whereas fall and late-fall are underestimated. Catch in 2007 and 2008 could not be expanded to estimate abundance at either Chipps Island or Sacramento due to incomplete sampling during the migration season at both locations. Tissue sampling has continued and will provide a better means of estimating abundance by race in 2008-2010. Estimating the abundance of “true” juvenile winter- and spring-run Chinook salmon entering and leaving the Delta is fundamental to understanding population status of these listed stocks.

Brandes, P. L. and J. S. McLain (2001). Juvenile chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. Fish Bulletin 179: Contributions to the biology of Central Valley salmonids. Volume 2. R. L. Brown. Sacramento, California Department of Fish and Game: 39-136.

All four races of juvenile Central Valley chinook salmon migrate through and many rear in the Sacramento-San Joaquin Delta and Estuary. Delta residence and migration is considered important in determining adult production, as it is generally believed that density dependent effects are minimal after this life stage. Populations of winter run and spring run are presently listed as endangered and threatened species, while the remaining populations in the Central Valley are candidate species. Actions in the Delta to improve survival are considered important in the recovery of these depressed populations. The tidally influenced freshwater Delta also is an important area for water management in California, as it is where the Central Valley and State Water Project pump large volumes of water to southern California. To document the effect of these various water management activities in the Delta on juvenile salmon, monitoring and special study activities have been conducted since the mid-1970s to the present. Changes in abundance in the Delta and estuary appear related to flow; high flows increase the use of the Delta and San Francisco Bay by fry. Relative survival of fry appears greater in the upper Sacramento River than in the Delta or bay, especially in the wetter years. Survival appears lower in the Central Delta relative to that in the North Delta in drier years for both fry and smolts. Fall-run smolt and late-fall-run yearling survival studies have found that diversion into the Central Delta via the Delta Cross Channel or Georgiana Slough reduces survival through the Delta. Experiments in the San Joaquin Delta have shown that survival appears greater for smolts that migrate down the mainstem San Joaquin River rather than through upper Old River. A temporary barrier in upper Old River was tested and found to improve survival for smolts originating from the San Joaquin basin. These specific experiments have identified management actions that could improve juvenile salmon survival through the Delta. In addition, indices of annual survival provide a way to compare survival through the

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and could be used to assess future restoration or management actions. This work demonstrates
how long-term scientific studies can be applied to address management and restoration
issues.

Brennan, M., S. Crooks, N. Monsen, J. Vandever, M. Orr, and P. Williams (2010). BREACH III physical processes: Hydrodynamics and wind/wave interactions. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Shallow water turbidity and phytoplankton production are recognized as being important for endangered species and regional food web support in the Sacramento-San Joaquin Delta. We are using hydrodynamic numerical modeling and field observations to understand the physical processes that sustain turbidity and phytoplankton production in and around Liberty Island (LI). Hydrodynamic circulation patterns and wind-generated waves are essential physical processes for characterizing the island’s current habitat as well as predicting the geomorphic evolution of LI. We are developing a two-dimensional hydrodynamic model (DELFT3D FLOW) of the LI Complex. We will present first phase results of circulation patterns within the open water and tule marsh portions of LI and exchange between LI and the surrounding channel network. To understand the spatial and temporal patterns of wind-waves, we are analyzing existing field data, collecting new wave observations, and modeling wind-waves with the DELFT3D SWAN (Simulating WAves Nearshore) model. We will present the wind-wave analysis of spatial distributions of wind, waves, and wave-induced erosion at annual and seasonal time scales. Over the course of this three year project, we want to understand how LI will evolve as the result of physical processes and whether site functioning can be improved by management actions. These numerical models will also provide spatial integration of datasets collected by project partners and collaborators and provide a platform for integrated regional analysis. Understanding the physical processes in Liberty Island, and the thresholds that define evolution will inform restoration planning both in Liberty Island and on adjacent areas.

Brennan, M. L., D.H. Schoellhamer, J.R. Burau, and S.G. Monismith (2002). Tidal asymmetry and variability of bed shear stress and sediment bed flux at a site in San Francisco Bay, USA. Fine sediment dynamics in the marine environment. J. C. Winterwerp, and C. Kranenburg, Elsevier Science B.V.: 93-108.
The relationship between sediment bed flux and bed shear stress during a pair of field experiments in a partially stratified estuary is examined in this paper. Time series of flow velocity, vertical density profiles, and suspended sediment concentration were measured continuously throughout the water column and intensely within 1 meter of the bed. These time series were analyzed to determine bed shear stress, vertical turbulent sediment flux, and mass of sediment suspended in the water column. Resuspension, as inferred from near-bed measurements of vertical turbulent sediment flux, was flood dominant, in accordance with the flood-dominant bed shear stress. Bathymetry-induced residual flow, gravitational circulation, and ebb tide salinity stratification contributed to the flood dominance. In addition to this flow-induced asymmetry, the erodibility of the sediment appears to increase during the first 2 hours of flood tide. Tidal asymmetry in bed shear stress and erodibility help explain an estuarine turbidity maximum that is present during flood tide but absent during ebb tide. Because horizontal advection was insignificant during most of the observation periods, the change in bed mass can be estimated from changes in the total suspended sediment mass. The square wave shape of the bed mass time series indicates that suspended sediment rapidly deposited in an unconsolidated or concentrated benthic suspension layer at slack tides and instantly resuspended when the shear stress became sufficiently large during a subsequent tide. The variability of bed mass associated with the spring/neap cycle (about 60 mg/cm2) is similar to that associated with the semidiurnal tidal cycle.

Bricker, J. D., S. Inagaki, et al. (2005). "Bed drag coefficient variability under wind waves in a tidal estuary." Journal of Hydraulic Engineering-Asce 131(6):

497-508.
In this paper we report the results of a study of the variation of shear stress and the bottom drag coefficient C-D with sea state and currents at a shallow site in San Francisco Bay. We compare shear stresses calculated from turbulent velocity measurements with the model of Styles and Glenn reported in 2000. Although this model was formulated to predict shear stress under ocean swell on the continental shelf, results from our experiments show that it accurately predicts these bottom stress under wind waves in an estuary. Higher up in the water column, the steady wind-driven boundary layer at the free surface overlaps with the steady bottom boundary layer. By calculating the wind stress at the surface and assuming a linear variation of shear between the bed and surface, however, the model can be extended to predict water column shear stresses that agree well with data. Despite the fidelity of the model, an examination of the observed stresses deduced using different wave-turbulence decomposition schemes suggests that wave-turbulence interactions are important, enhancing turbulent shear stresses at wave frequencies.

Brooks, M., E. Fleishman, L.R. Brown, P.W. Lehman, I. Werner, N. Scholz, C. Mitchelmore, and D. Schlenk (2010). Potential contributions of contaminants to the decline of pelagic fishes in the San Francisco Estuary, California, U.S.A. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The San Francisco Estuary has been altered by major hydrologic projects, mining and other land uses, invasive species, and algal blooms. Additional stressors include episodic drought, mixtures of pesticides (>20 million kg pesticide products purchased annually), heavy metals, nutrients, and pharmaceuticals. Around 2000, there were step declines in abundances of multiple pelagic fishes despite some years of high precipitation that were expected to increase recruitment and abundances. Native species of concern include delta smelt (Hypomesus transpacificus; listed as endangered under the U.S. federal and California endangered species acts) and longfin smelt (Spirinchus thaleichthys; listed as threatened under the California act). Abundances of introduced threadfin shad (Dorosoma petenense), a major prey species, and introduced striped bass (Morone saxatilis), a popular sport fish, also are declining. We review the spatial overlap between sensitive life stages and the mechanisms by which contaminants in conjunction often exacerbated by non-contaminant stressors may contribute to declines.

Brooks, M., E. Fleishman, et al. (2012). "Life Histories, Salinity Zones, and Sublethal Contributions of Contaminants to Pelagic Fish Declines Illustrated with a Case Study of San Francisco Estuary, California, USA." Estuaries and Coasts 35(2): 603-621.

Brown, C. L., and S.N. Luoma (1995). "Use of the euryhaline bivalve Potamocorbula amurensis as a biosentinal species to assess trace metal contamination in San Francisco Bay." Marine Ecology Progress Series 124: 14.
Potamocorbula amurensis was assessed as a biosentinel species in San Francisco Bay, California, USA. Uptake of metal in both the laboratory and field showed that P. amurensis was sufficiently responsive to Ag, Cd, Cr, Ni and V to detect environmental differences in exposure. It was less suitable as an indicator of Cu and Zn contamination. Concentration factors for P. amurensis were: Ag, 386000; Cd, 50200; Cr. 36600; Cu, 12200; Ni, 5200; and Zn, 115500. Samples were collected from 6 stations throughout the bay at near-monthly intervals from January 1991 to March 1992. Variability within a collection was influenced by gut content and animal size. Other sources of variability were time (coefficient of variation (CV) = 10 to 21 %), small-scale spatial variability (within 3 km, CV = 10 to 25%), and large-scale spatial variability (CV = 3.3 to 12.4%). Depuration for 48 h was necessary to mitigate bias from gut content. Precision was improved by analyzing large numbers of individuals (60 to 120) separated into several (5 to 14) composites at each collection and by determining, from regression, the mean and variance for samples with significant correlations between metal concentration and shell length. Repeated monthly sampling increased the accuracy of long-term site characterizations. Temporal variability was small because of drought. The grand means of the concentrations of Ag, Cd, Cr, Ni, and V in the tissues of P. amurensis at each station for the 15 mo period revealed persistent contamination from

industrialized Suisun Bay to the mouth of San Francisco Bay. Demonstration of responsiveness, precision and accuracy should be a prerequisite for the optimal use of biosentinels.

Brown, C. L., F. Parchaso, et al. (2003). "Assessing toxicant effects in a complex estuary: A case study of effects of silver on reproduction in the bivalve, Potamocorbula amurensis, in San Francisco Bay." Human and ecological risk assessment 9: 95-119.
Contaminant exposures in natural systems can be highly variable. This variability is superimposed upon cyclic variability in biological processes. Together, these factors can confound determination of contaminant effects. Long term, multidisciplined studies with high frequency sampling can be effective in overcoming such obstacles. While studying trace metal contamination in the tissues of the clam, Potamocorbula amurensis, in the northern reach of San Francisco Bay, an episode of high Ag concentrations was identified (maximum of 5.5 mug g(-1)) at two mid-estuary sites. High concentrations were not seen in clams up-estuary (maximum of 1.92 mug g(-1)) from these sites and were reduced down-estuary (maximum of 2.67 mug g(-1)). Silver is not common naturally in the environment, so its elevated presence is usually indicative of anthropogenic influences such as municipal and industrial discharge. Monthly sampling of reproductive status of clams characterized the reproductive cycle and differences in the patterns of reproductive activity that corresponded to changes in Ag tissue concentrations. The proportion of reproductive clams was less than 60% during periods when tissue concentrations were high (generally >2 mug g(-1)). When tissue concentrations of Ag decreased (less than or equal to1 mug g(-1)), the proportion of reproductive clams was 80 to 100%. A comparison between the annual proportion of reproductive clams and annual Ag tissue concentrations showed a significant negative correlation. No other measured environmental variables were correlated with reproductive impairment. The weight-of-evidence approach strongly supports a cause and effect relationship between Ag contamination and reduced reproductive activity in P. amurensis.

Brown, C. L., G. Young, et al. (1987). "Preliminary report on the physiological status of striped bass in the Carquinez Strait die-off." Fisheries Research 6: 5-16.
Tissue and blood samples from moribound striped class (Morone saxatilis) collected during the summer 1985 die-off in the Carquinez Strait were analysed. Despite the small number of specimens available differences between moribund fish and controls were striking and consistent enough for the basis this preliminary report. Comparison of serum and tissue analyses from three moribund samples with four relatively healthy controls, indicated that liver dysfunction is an important aspect of the pathology of fish in this die-off. This conclusion was based on data on histological indications of hepatic lesions and inflammation, hormone imbalances and accumulations of uric acid, bilirubin and alkaline phosphatase in the plasma. Abnormal variation in plasma glucose levels, at both high and low extremes, may reflect severe disruption of carbohydrate metabolism in the moribund fish. The causes of this liver damage have not yet been identified.

Brown, K. J. and G. B. Pasternack (2004). "The geomorphic dynamics and environmental history of an upper deltaic floodplain tract in the Sacramento-San Joaquin Delta, California, USA." Earth Surface Processes and Landforms 29(10): 1235-1258.
A multi-proxy approach was used to examine the geomorphic dynamics and environmental history of an upper deltaic floodplain tract in the Sacramento-San Joaquin Delta, California. Three long cores were collected from the McCormack-Williamson Tract (MWT) and these cores were analyzed for bulk density, loss-on-ignition, fine (clay and silt) content, Al concentration, magnetic susceptibility, pollen, and charcoal. Radiocarbon dates obtained for the cores were converted into calendar years and an age-depth model was constructed. Long-term vertical accretion and sedimentation rates were estimated from the age-depth model. Cross-core relations show that coarse sediment generally accumulates more rapidly and has greater magnetic susceptibility compared to fine sediment. Percentage fine and LOI data show a strong linear relationship that indicates flooding is the primary mechanism for the deposition of particular organic matter on the floodplain and that landscape wash load has contributed a highly consistent fraction of persistent organic matter averaging 5.5 per cent to the site. Down-core grain size

profiles show two hydrological domains in the cores, namely millennial fine-coarse fluctuations superimposed on general up-core fining. Coarse sediment is viewed as channel or near-channel overbank deposits, whereas fine deposits are considered to be distal overbank flood deposits. The coarse-fine fluctuations are indicative of changing depositional settings as channels migrated laterally across MWT, whereas the upward fining trend reflects a combination of self-limiting overbank deposition as floodplain elevation increased and decreasing competence as sea-level rise reduced flood-pulse energy slopes. MWT has been cross-cut and incised numerous times in the past, only to have the channels abandoned and subsequently filled by fine sediment. The channels around MWT attained their modem configuration about 4000 years ago. MWT likely came under tidal influence at about 2500 cal BP. Wetlands have recently developed on MWT, but they are inorganic sediment dominated. Copyright (C) 2004 John Wiley Sons, Ltd.

Brown, K. L. and G. B. Pasternack (2005). "A palaeoenvironmental reconstruction to aid in the restoration of floodplain and wetland habitat on an upper deltaic plain, California, USA." Environmental Conservation 32: 103-116.
While tens of millions of dollars have been spent on land acquisition and planning for current and future floodplain and wetland restoration in the Sacramento-San Joaquin Delta, knowledge of the historical processes and landscape heterogeneity that are helpful in guiding the environmental restoration are often scarce. This study used palaeoenvironmental reconstruction to increase the historical perspective, with the aim of improving environmental management. Twelve sediment cores collected from the McCormack-Williamson Tract (MWT) leveed farmland and the juxtaposed Delta Meadows (DM) tidal wetland were sampled for a suite of environmental proxies. MWT was a non-tidal flood plain during much of the late-Holocene, with a mosaic of other habitats including dry uplands, riparian forests, and freshwater wetlands persisting nearby. Comparison with the regional sea-level history suggests that the upper delta gradually came under tidal influence 3000–800 calendar years before present (cal BP). Despite this, floodplain landforms and habitats prevailed at DM from 3650–330 cal BP, after which wetlands expanded, suggesting that a flood-based disturbance regime typified the upper delta for most of the late-Holocene. Recently, the upper deltaic plain has been profoundly disturbed by agriculture and other activities, rendering significant loss of habitat. It is believed that a flood-based disturbance regime will recur at MWT if the levees surrounding the tract are intentionally breached as planned for restoration, culminating in a variety of habitats similar to pre-agricultural conditions. Concentrations of Hg, Pb, As, and P pollutants elevated several-fold in surficial sediments are of particular concern, potentially becoming problematic after restoration.

Brown, L. R., P.B. Moyle, W.A. Bennett, and B.D. Quelvog (1992). "Implications of morphological variation among populations of California roach Lavinia symmetricus (Cyprinidae) for conservation policy." Biological Conservation 62(1): 1-10.
The California roach Lavinia symmetricus is a small cyprinid native to Central California. Populations of roach are presently isolated from one another due to degradation of stream habitats between them. We examined eight populations, each from a tributary system of the San Joaquin River, to determine if morphological differences existed among them. These tributaries are now isolated from one another by dams or areas of unsuitable habitat. We found significant differences among drainages for all of the characters studied. Discriminant analysis classified 70% of the individuals to the correct drainage. The differences were not clinal because adjacent drainages were not grouped together in discriminant space. The most distinct population was as different from a nearby population (36 stream km) as from populations from other more distant tributaries and could possibly merit subspecies status. These results suggest that each population has been isolated long enough to develop morphological adaptions to local environment conditions. With one exception, the differences among the populations were too small for formal taxonomic recognition but suggest that management should focus on preserving local populations throughout the species' range, rather than scattered populations in a few reserves. This policy would serve to protect the genetic diversity of California roach, local aquatic habitats, and other even more poorly known species.

Brown, L. R., and P.B. Moyle (1993). "Distribution, ecology, and status of the fishes of the San Joaquin River drainage, California." California Fish and Game 79(3): 96-114.

Brown, L. R. (1996). Aquatic biology of the San Joaquin-Tulare Basins, California: analysis of available data through 1992. Washington D.C., U.S. Government Printing Office.

Brown, L. R. (1997). "Concentrations of chlorinated organic compounds in biota and bed sediment in streams of the San Joaquin Valley, California." Archives of Environmental Contamination and Toxicology 33(4): 357-368.

Samples of resident biota and bed sediments were collected in 1992 from 18 sites on or near the floor of the San Joaquin Valley, California, for analysis of 33 organochlorine compounds. The sites were divided into five groups on the basis of physiographic region and land use. Ten compounds were detected in tissue, and 15 compounds were detected in bed sediment. The most frequently detected compound in both media was p,p′-DDE. Concentrations of ΣDDT (sum of o,p′- and p,p′ forms of DDD, DDE, and DDT) were statistically different among groups of sites for both tissue and sediment (Kruskal-Wallis, $p<0.05$). Concentrations in both media were highest in streams draining the west side of the valley. Concentrations of ΣDDT in tissue were significantly correlated with specific conductance, pH, and total alkalinity ($p<0.05$), which are indicators of the proportion of irrigation return flows in stream discharge. Concentrations in sediment on a dry-weight basis were not correlated with these water-quality parameters, but total organic carbon (TOC) normalized concentrations were significantly correlated with specific conductance and pH ($p<0.05$). Regressions of the concentration of ΣDDT in tissue, as a function of ΣDDT in bed sediment, were significant and explained up to 76% of the variance in the data. The concentration of ΣDDT in sediment may be related to mechanisms of soil transport to surface water with bioavailability of compounds related to the concentration of TOC in sediment. The results of this study did not indicate any clear advantage to using either bed sediment or tissues in studies of organochlorine chemicals in the environment. Some guidelines for protection of fish and wildlife were exceeded. Concentrations of organochlorine chemicals in biota, and perhaps sediment, have declined from concentrations measured in the 1970s and 1980s, but remain high compared to other regions of the United States.

Brown, L. R., and P.B. Moyle (1997). "Invading species in the Eel River, California: Successes, failures, and relationships with resident species." Environmental Biology of Fishes 49(3): 271-291.

We examined invasions of non-native fishes into the Eel River, California. At least 16 species of fish have been introduced into the drainage which originally supported 12-14 fish species. Our study was prompted by the unauthorized introduction in 1979 of Sacramento squawfish, Ptychocheilus grandis, a large predatory cyprinid. From 1986 to 1990, we conducted growth and diet studies of squawfish, conducted intensive surveys of the distribution and habitat associations of both native and introduced species, and examined the nature of species-habitat and interspecies relationships. We found no evidence for increased growth or expanded feeding habits, compared to native populations, of Sacramento squawfish as they invaded the Eel River drainage. Ten of the introduced species were well established, with four species limited to a reservoir and six species established in streams. The success or failure of introductions of stream species appeared to be a function of the ability of a species to survive the fluctuating, highly seasonal, flow regime. The present mixture of native and exotic species has not formed stable fish assemblages but it seems likely that four habitat-associated assemblages will develop. The overall effect of the successful species introductions has been to assemble a group of species, with some exceptions, that are native to and occur together in many California streams. The assemblages now forming are similar to those found in other California streams. The assemblage characterized by squawfish and suckers is likely to be resistant to invasion, in the absence of human caused habitat modifications.

Brown, L. R. (2000). "Fish communities and their associations with environmental variables, lower San Joaquin River drainage, California." Environmental Biology of

Fishes 57(3): 251-269.
Twenty sites in the lower San Joaquin River drainage, California, were sampled from 1993 to 1995 to characterize fish communities and their associations with measures of water quality and habitat quality. The feasibility of developing an Index of Biotic Integrity was assessed by evaluating four fish community metrics, including percentages of native fish, omnivorous fish, fish intolerant of environmental degradation, and fish with external anomalies. Of the thirty-one taxa of fish captured during the study, only 10 taxa were native to the drainage. Multivariate analyses of percentage data identified four site groups characterized by different groups of species. The distributions of fish species were related to specific conductance, gradient, and mean depth; however, specific conductance acted as a surrogate variable for a large group of correlated variables. Two of the fish community metrics – percentage of introduced fish and percentage of intolerant fish – appeared to be responsive to environmental quality but the responses of the other two metrics – percentage of omnivorous fish and percentage of fish with anomalies – were less direct. The conclusion of the study is that fish communities are responsive to environmental conditions, including conditions associated with human-caused disturbances, particularly agriculture and water development. The results suggest that changes in water management and water quality could result in changes in species distributions. Balancing the costs and benefits of such changes poses a considerable challenge to resource managers.

Brown, L. R., and J.T. May (2000). "Macroinvertebrate assemblages on woody debris and their relations with environmental variables in the lower Sacramento and San Joaquin River drainages, California." Environmental Monitoring and Assessment 64(1): 311-329.
Data from 25 sites were used to evaluate associations between macroinvertebrate assemblages on large woody debris (snags) and environmental variables in the lower San Joaquin and Sacramento River drainages in California as part of the U.S. Geological Survey's National Water Quality Assessment Program. Samples were collected from 1993 to 1995 in the San Joaquin River drainage and in 1996 and 1997 in the Sacramento River drainage. Macroinvertebrate taxa were aggregated to the family (or higher) level of taxonomic organization, resulting in 39 taxa for analyses. Only the 31 most common taxa were used for two-way indicator species analysis (TWINSPAN) and canonical correspondence analysis (CCA). TWINSPAN analysis defined four groups of snag samples on the basis of macroinvertebrate assemblages. Analysis of variance identified differences in environmental and biotic characteristics among the groups. These results combined with the results of CCA indicated that mean dominant substrate type, gradient, specific conductance, water temperature, percentage of the basin in agricultural land use, percentage of the basin in combined agricultural and urban land uses, and elevation were important factors in explaining assemblage structure. Macroinvertebrate assemblages on snags may be useful in family level bioassessments of environmental conditions in valley floor habitats.

Brown, L. R. (2003). "An introduction to the San Francisco Estuary tidal wetlands restoration series." San Francisco Estuary and Watershed Science 1: 1.
Abstract Restoration of tidal wetlands may provide an important tool for improving ecological health and water management for benecial uses of the San Francisco Estuary (hereafter \Estuary"). Given the large losses of tidal wetlands from San Francisco Bay and the Sacramento-San Joaquin Delta in the last 150 years, it seems logical to assume that restoring tidal wetlands will have benefits for a variety of aquatic and terrestrial native species that have declined during the same time period. However, many other changes have also occurred in the Estuary con- current with the declines of native species. Other factors that might be important in species declines include the effects of construction of upstream dams, large and small water diversions within the Sacramento-San Joaquin Delta, agricultural pesticides, trace elements from indus- trial and agricultural activities, and invasions of alien species. Discussions among researchers, managers, and stakeholders have identified a number of uncertainties regarding the potential benets of tidal wetland restoration. The articles of the Tidal Wetlands Restoration Series address four major issues of concern. Stated as questions, these are: 1. Will tidal wetland restoration enhance populations of native shes? 2. Will wetland

restoration increase rates of methylation of mercury? 3. Will primary production and other ecological processes in restored tidal wetlands result in net export of organic carbon to adjacent habitats, resulting in enhancement of the food web? Will the carbon produced contribute to the formation of disinfection byproducts when disinfected for use as drinking water? 4. Will restored tidal wetlands provide long-term ecosystem benets that can be sustained in response to ongoing physical processes, including sedimentation and hydrodynamics? Reducing the uncertainty surrounding these issues is of critical importance because tidal wet- land restoration is assumed to be a critical tool for enhancement of native species and ecosystem processes in the Estuary.

Brown, L. R. (2003). "Potential effects of organic carbon production on ecosystems and drinking water quality." San Francisco Estuary and Watershed Science 1: Issue 1 Article 3.
Restoration of tidal wetlands in the Sacramento-San Joaquin Delta (Delta) is an impor- tant component of the Ecosystem Restoration Program of the CALFED Bay-Delta Program (CALFED). CALFED is a collaborative eort among state and federal agencies to restore the ecological health and improve water management of the Delta and San Francisco Bay (Bay). Tidal wetland restoration is intended to provide valuable habitat for organisms and to improve ecosystem productivity through export of various forms of organic carbon, including both algae and plant detritus. However, the Delta also provides all or part of the drinking water for over 22 million Californians. In this context, increasing sources of organic carbon may be a problem because of the potential increase in the production of trihalomethanes and other disinfection by-products created during the process of water disinfection. This paper reviews the existing information about the roles of organic carbon in ecosystem function and drinking water quality in the Bay-Delta system, evaluates the potential for interaction, and considers major uncer- tainties and potential actions to reduce uncertainty. In the last 10 years, substantial progress has been made on the role of various forms of organic carbon in both ecosystem function and drinking water quality; however, interactions between the two have not been directly addressed. Several ongoing studies are beginning to address these interactions, and the results from these studies should reduce uncertainty and provide focus for further research.

Brown, L. R. (2003). "A summary of the San Francisco tidal wetlands restoration series." San Francisco Estuary and Watershed Science 1: 6.
The four topical articles of the Tidal Wetlands Restoration Series summarized and syn- thesized much of what is known about tidal wetlands and tidal wetland restoration in the San Francisco Estuary (hereafter "Estuary"). Despite a substantial amount of available informa- tion, major uncertainties remain. A major uncertainty with regard to fishes is the net benefit of restored tidal wetlands relative to other habitats for native shes in different regions of the Estuary given the presence of numerous invasive alien species. With regard to organic carbon, a major uncertainty is the net benefit of land use change given uncertainty about the quantity and quality of different forms of organic carbon resulting from different land uses. A major challenge is determining the flux of organic carbon from open systems like tidal wetlands. Con- verting present land uses to tidal wetlands will almost certainly result in increased methylation of mercury at the local scale with associated accumulation of mercury within local food webs. Howver, it is unclear if such local accumulation is of concern for fish, wildlife or humans at the local scale or if cumulative effects at the regional scale will emerge. Based on available information it is expected that restored tidal wetlands will remain stable once constructed; however, there is uncertainty associated with the available data regarding the balance of sed- iment accretion, sea-level rise, and sediment erosion. There is also uncertainty regarding the cumulative effect of many tidal restoration projects on sediment supply. The conclusions of the articles highlight the need to adopt a regional and multidisciplinary approach to tidal wetland restoration in the Estuary. The Science Program of the CALFED effort provides an appropriate venue for addressing these issues.

Brown, L. R. (2003). "Will tidal wetland restoration enhance populations of native fishes?" San Francisco Estuary and Watershed Science 1: Issue 1 Article 2.

Restoration of tidal wetlands might enhance populations of native shes in the San Fran-
cisco Estuary of California. The purpose of this paper is to: (1) review the currently available
information regarding the importance of tidal wetlands to native shes in the San Francisco
Estuary, (2) construct conceptual models on the basis of available information, (3) identify
key areas of scientic uncertainty, and (4) identify methods to improve conceptual models
and reduce uncertainty. There are few quantitative data to suggest that restoration of tidal
wetlands will substantially increase populations of native shes. On a qualitative basis, there
is some support for the idea that tidal wetland restoration will increase populations of some
native shes; however, the species deriving the most benet from restoration might not be of
great management concern at present. Invasion of the San Francisco Estuary by alien plants
and animals appears to be a major factor in obscuring the expected link between tidal wetlands
and native shes. Large-scale adaptive management experiments (>100 hectares) appear to
be the best available option for determining whether tidal wetlands will provide signicant
benet to native shes. Even if these experiments are unsuccessful at increasing native sh
populations, the restored wetlands should benet native birds, plants, and other organisms.

Brown, L. R., and D. Michniuk (2007). "Littoral fish assemblages of the alien-dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003." Estuaries and Coasts 30(1): 186-200.

We analyzed monthly boat electrofishing data to characterize the littoral fish assemblages of five regions of the Sacramento-San Joaquin Delta (northern, southern, eastern, western, and central), California, during two sampling periods, 1980–1983 (1980s) and 2001–2003 (2000s), to provide information pertinent to the restoration of fish populations in this highly altered estuary. During the 1980s, almost 11,000 fish were captured, including 13 native species and 24 alien species. During the 2000s, just over 39,000 fish were captured, including 15 native species and 24 alien species. Catch per unit effort (CPUE) of total fish, alien fish, and centrarchid fish were greater in the 2000s compared with the 1980s, largely because of increased centrarchid fish CPUE. These differences in CPUE were associated with the spread of submerged aquatic vegetation (SAV), particularly an alien aquatic macrophyte,Egeria densa. Native fish CPUE declined from the 1980s to the 2000s, but there was no single factor that could explain the decline. Native fish were most abundant in the northern region during both sampling periods. Nonmetric multidimensional scaling indicated similar patterns of fish assemblage composition during the two sampling periods, with the northern and western regions characterized by the presence of native species. The separation of the northern and western regions from the other regions was most distinct in the 2000s. Our results suggest that native fish restoration efforts will be most successful in the northern portion of the Delta. Management decisions on the Delta should include consideration of possible effects on SAV in littoral habitats and the associated fish assemblages and ecological processes.

Brown, L. R. (2010). An update on the UC Santa Barbara Workgroups. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Brown, L. R., W. Bennett, R.W. Wagner, T. Morgan-King, N. Knowles, F. Feyrer, D.H. Schoellhamer, M.T. Stacey, and M. Dettinger (2013). "Implications for Future

Survival of Delta Smelt from Four Climate Change Scenarios for the Sacramento-San Joaquin Delta, California." Estuaries and Coasts.

Changes in the position of the low salinity zone, a habitat suitability index, turbidity, and water temperature modeled from four 100-year scenarios of climate change were evaluated for possible effects on delta smelt Hypomesus transpacificus, which is endemic to the Sacramento–San Joaquin Delta. The persistence of delta smelt in much of its current habitat into the next century appears uncertain. By mid-century, the position of the low salinity zone in the fall and the habitat suitability index converged on values only observed during the worst droughts of the baseline period (1969–2000). Projected higher water temperatures would render waters historically inhabited by delta smelt near the confluence of the Sacramento and San Joaquin rivers largely uninhabitable. However, the scenarios of climate change are based on assumptions that require caution in the interpretation of the results. Projections like these provide managers with a useful tool for anticipating long-term challenges to managing fish populations and possibly adapting water management to ameliorate those challenges.

Brown, L. R. and M. L. Bauer (2010). "Effects of hydrologic infrastructure on flow regimes of California's Central Valley rivers: Implications for fish populations." River Research and Applications 26(6): 751-765.

Alteration of natural flow regimes is generally acknowledged to have negative effects on native biota; however, methods for defining ecologically appropriate flow regimes in managed river systems are only beginning to be developed. Understanding how past and present water management has affected rivers is an important part of developing such tools. In this paper, we evaluate how existing hydrologic infrastructure and management affect streamflow characteristics of rivers in the Central Valley, California and discuss those characteristics in the context of habitat requirements of native and alien fishes. We evaluated the effects of water management by comparing observed discharges with estimated discharges assuming no water management (‘full natural runoff’). Rivers in the Sacramento River drainage were characterized by reduced winter–spring discharges and augmented discharges in other months. Rivers in the San Joaquin River drainage were characterized by reduced discharges in all months but particularly in winter and spring. Two largely unaltered streams had hydrographs similar to those based on full natural runoff of the regulated rivers. The reduced discharges in the San Joaquin River drainage streams are favourable for spawning of many alien species, which is consistent with observed patterns of fish distribution and abundance in the Central Valley. However, other factors, such as water temperature, are also important to the relative success of native and alien resident fishes. As water management changes in response to climate change and societal demands, interdisciplinary programs of research and monitoring will be essential for anticipating effects on fishes and to avoid unanticipated ecological outcomes. Published in 2009 by John Wiley & Sons, Ltd.

Brown, L. R. and T. Ford (2002). "Effects of flow on the fish communities of a regulated California river: implications for managing native fishes." River Research and Applications 18(4): 331-342.

We assessed the importance of flow regime to the success of native and non-native fish species by analysing winter/spring seining data collected from 1987 to 1997 on the resident fish communities of the lower Tuolumne River, California. The data were analysed using regression models to predict the percentage of non-native fish at a site. The regression models included various combinations of the variables longitudinal location of the site, mean April/May stream discharge in the year of sampling, and mean April/May stream discharge in the previous year. Comparison of the models indicated that the best model included longitudinal location and stream discharge in the previous year. This model is consistent with the hypothesis that flow in the previous year differentially affects reproductive success of native and non-native species and thus the resulting community sampled in the following winter/spring. A detrended correspondence analysis of percentage abundance species data identified a co-occurring group of native species and a co-occurring group of non-native species with the non-native red shiner (Cyprinella lutrensis) grouping separately. The differing reproductive strategies of the species were consistent with the hypothesis concerning spawning success. Our results indicate that flow regime is an important determinant of the reproductive success of native and non-native fish species in regulated rivers. Manipulations of flow regime are a potentially powerful tool for managing native fish species, but should be considered in combination with other restoration efforts and in the context of ecosystem restoration.

Brown, L. R., W. Kimmerer, et al. (2008). "Managing water to protect fish: a review of California's Environmental Water Account." Environmental Management 43: 357-368.
The Sacramento-San Joaquin Delta, the landward reach of the San Francisco Estuary, provides habitat for threatened delta smelt, endangered winter-run Chinook salmon, and other species of concern. It is also the location of huge freshwater diversion facilities that entrain large numbers of fish. Reducing the entrainment of listed fishes into these facilities has required curtailment of pumping, reducing the reliability of water deliveries. We reviewed the first 5 years (2001–2005) of the Environmental Water Account (EWA), a program instituted to resolve conflicts between protecting listed fishes and providing a reliable water supply. The EWA provided fishery agencies with control over 0.2–0.4 km3 of water to be used for fish protection at no cost to users of exported water, and fish agencies guaranteed no disruption of water supply for fish protection. The EWA was successful in reducing uncertainty in water supply; however, its contribution to the recovery of listed fishes was unclear. We estimated the effectiveness of the EWA to be modest, increasing the survival of winter-run Chinook salmon by 0–6% (dependent on prescreen mortality), adult delta smelt by 0–1%, and juvenile delta smelt by 2–4%. Allocating EWA water for a single life stage of one species could provide larger gains in survival. An optimally allocated EWA of equal size to the median of the first 5 years could increase abundance of juvenile delta smelt up to 7% in the springs of dry years. If the EWA is to become a long-term program, estimates of efficacy should be refined. If the program is to be held accountable for quantitative increases in fish populations, it will be necessary to integrate scientific, possibly experimental, approaches.

Brown, L. R. and J. T. May (2000). "Macroinvertebrate assemblages on woody debris and their relations with environmental variables in the lower Sacramento and San Joaquin River drainages, California." Environmental Monitoring and Assessment 64(1): 311-329.
Data from 25 sites were used to evaluate associations between macroinvertebrate assemblages on large woody debris (snags) and environmental variables in the lower San Joaquin and Sacramento River drainages in California as part of the U.S. Geological Survey's National Water Quality Assessment Program. Samples were collected from 1993 to 1995 in the San Joaquin River drainage and in 1996 and 1997 in the Sacramento River drainage. Macroinvertebrate taxa were aggregated to the family (or higher) level of taxonomic organization, resulting in 39 taxa for analyses. Only the 31 most common taxa were used for two-way indicator species analysis (TWINSPAN) and canonical correspondence analysis (CCA). TWINSPAN analysis defined four groups of snag samples on the basis of macroinvertebrate assemblages. Analysis of variance identified differences in environmental and biotic characteristics among the groups. These results combined with the results of CCA indicated that mean dominant substrate type, gradient, specific conductance, water temperature, percentage of the basin in agricultural land use, percentage of the basin in combined agricultural and urban land uses, and elevation were important factors in explaining assemblage structure. Macroinvertebrate assemblages on snags may be useful in family level bioassessments of environmental conditions in valley floor habitats.

Brown, L. R. and J. T. May (2006). "Variation in Spring Nearshore Resident Fish Species Composition and Life Histories in the Lower San Joaquin Watershed and Delta." San Francisco Estuary and Watershed Science 4(2): Article 1.

Brown, L. R. and D. Michniuk (2007). "Littoral fish assemblages of the alien-dominated Sacramento - San Joaquin Delta, California, 1980-1983 and 2001-2003." Estuaries and Coasts 30(1): 186-200.
We analyzed monthly boat electrofishing data to characterize the littoral fish assemblages of five regions of the Sacramento-San Joaquin Delta (northern,

southern, eastern, western, and central), California, during two sampling periods, 1980-1983 (1980s) and 2001-2003 (2000s), to provide information pertinent to the restoration of fish populations in this highly altered estuary. During the 1980s, almost 11,000 fish were captured, including 13 native species and 24 alien species. During the 2000s, just over 39,000 fish were captured, including 15 native species and 24 alien species. Catch per unit effort (CPUE) of total fish, alien fish, and centrarchid fish were greater in the 2000s compared with the 1980s, largely because of increased centrarchid fish CPUE. These differences in CPUE were associated with the spread of submerged aquatic vegetation (SAV), particularly an alien aquatic macrophyte Egeria densa. Native fish CPUE declined from the 1980s to the 2000s, but there was no single factor that could explain the decline. Native fish were most abundant in the northern region during both sampling periods. Nonmetric multidimensional scaling indicated similar patterns of fish assemblage composition during the two sampling periods, with the northern and western regions characterized by the presence of native species. The separation of the northern and western regions from the other regions was most distinct in the 2000s. Our results suggest that native fish restoration efforts will be most successful in the northern portion of the Delta. Management decisions on the Delta should include consideration of possible effects on SAV in littoral habitats and the associated fish Assemblages and ecological processes.

Brown, L. R. and P. B. Moyle (1993). "Distribution, ecology, and status of the fishes of the San Joaquin River drainage, California." California Fish and Game 79: 96-114.

In 1985 and 1986 we sampled streams of the San Joaquin River drainage in south-central California. The purposes of the survey were: (i) to see if further declines in native fish populations had occurred since 1970 when they were last surveyed; (ii) to verify the species distributions and species-habitat relationships observed in previous studies; (iii) to verify the species assemblages observed in previous studies; and (iv) to determine the status of the recently described Kern brook lamprey (Lampetra hubbsi). We also reviewed the status of the native fish fauna as compared to pre-European times. Only 11 species of the original fauna of 19 species were found and only 6 of the 11 were common. Hardhead (Mylopharodon conocephalus) and hitch (Lavinia exilicauda) were found in fewer localities than in 1970. The decline in hardhead was associated with an expansion of smallmouth bass (Micropterus dolomieu) populations. Three assemblages of native species were identified, in agreement with earlier studies. A fourth assemblage identified in earlier studies, composed largely of introduced fishes, was divided into two subgroups on the basis of our analysis. Each assemblage of species was associated with a distinct set of habitat characteristics. Populations of Kern brook lamprey were found in the Kaweah, Kings, San Joaquin, and Merced rivers. Lampreys were absent from the lower reaches of the rivers and, except in the Kings River, were only found below major dams. In the Kings River lampreys were captured above and below Pine Flat Reservoir. Because the populations are restricted in range, effectively isolated from one another, and all but one can be affected by reservoir operations, special protection for them is warranted.

Brown, L. R. and P. B. Moyle (2005). "Native Fishes of the Sacramento-San Joaquin Drainage, California: A History of Decline." American Fisheries Society Symposium 45: 75-898.

In this paper, we review information regarding the status of the native fishes of the combined Sacramento River and San Joaquin River drainages (hereinafter the "Sacramento-San Joaquin drainage") and the factors associated with their declines. The Sacramento-San Joaquin drainage is the center of fish evolution in California, giving rise to 17 endemic species of a total native fish fauna of 28 species. Rapid changes in land use and water use beginning with the Gold Rush in the 1850s and continuing to the present have resulted in the extinction, extirpation, and reduction in range and abundance of the native fishes. Multiple factors are associated with the declines of native fishes, including habitat alteration and loss, water storage and diversion, flow alteration, water quality, and invasions of alien species. Although native fishes can be quite tolerant of stressful physical conditions, in some rivers of the drainage the physical habitat has been altered to the extent that it is now more suited for alien species. This interaction of environmental changes and invasions of alien species makes it difficult to predict the benefits of restoration efforts to native fishes. Possible effects of climate change on California's aquatic habitats add additional complexity to restoration of native fishes. Unless protection and restoration of native fishes is explicitly considered in future water management decisions, declines are likely to continue.

Brown, L. R., P. B. Moyle, et al. (1992). "Implications of morphological variation among populations of California roach Lavinia symmetricus (Cyprinidae) for conservation policy." Biological Conservation 62(1): 1-10.

The California roach Lavinia symmetricus is a small cyprinid native to Central California. Populations of roach are presently isolated from one another due to degradation of stream habitats between them. We examined eight populations, each from a tributary system of the San Joaquin River, to determine if morphological differences existed among them. These tributaries are now isolated from one another by dams or areas of unsuitable habitat. We found significant differences among drainages for all of the characters studied. Discriminant analysis classified 70% of the individuals to the correct drainage. The differences were not clinal because adjacent drainages were not grouped together in discriminant space. The most distinct population was as different from a nearby population (36 stream km) as from populations from other more distant tributaries and could possibly merit subspecies status. These results suggest that each population has been isolated long enough to develop morphological adaptions to local environmental conditions. With one exception, the differences among the populations were too small for formal taxonomic recognition but suggest that management should focus on preserving local populations throughout the species' range, rather than scattered populations in a few reserves. This policy would serve to protect the genetic diversity of California roach, local aquatic habitats, and other even more poorly known species.

Brown, L. R., J. K. Thompson, et al. (2007). "Population density, biomass, and age-class structure of an invasive clam Corbicula fluminea in rivers of the lower San Joaquin River watershed, California." Western North American Naturalist 67: 572-586.

Corbicula fluminea is well known as an invasive filter-feeding freshwater bivalve with a variety of effects on ecosystem processes. However, C. fluminea has been relatively unstudied in the rivers of the western United States. In June 2003, we sampled C. fluminea at 16 sites in the San Joaquin River watershed of California, which was invaded by C. fluminea in the 1940s. Corbicula fluminea was common in 2 tributaries to the San Joaquin River, reaching densities of 200 clams times m super(-2), but was rare in the San Joaquin River. Biomass followed a similar pattern. Clams of the same age were shorter in the San Joaquin River than in the tributaries. Distribution of clams was different in the 2 tributaries, but the causes of the difference are unknown. The low density and biomass of clams in the San Joaquin River was likely due to stressful habitat or to water quality, because food was abundant. The success of C. fluminea invasions and subsequent effects on trophic processes likely depends on multiple factors. As C. fluminea continues to expand its range around the world, questions regarding invasion success and effects on ecosystems will become important in a wide array of environmental settings.

Brown, M., and D. Colby (2010). Juvenile salmonid habitat use of stream channel restoration in Clear Creek: Longer-term observations related to sustainability. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The CALFED and CVPIA funded Lower Clear Creek Floodway Rehabilitation Project is a multi-phase project, designed to restore 2.5 miles of stream channel and floodplain habitat. While the project met its adult habitat goals, we evaluated the secondary, juvenile-habitat goal of the project. Clear Creek is a high priority watershed for CALFED, which has funded similar large-scale restoration projects in other watersheds. Direct measurement of juvenile densities has rarely been performed in these other projects. We evaluated two objectives: 1) attain average juvenile

densities equal to or greater than control reaches, and 2) retain juvenile habitats for at least 5 years, with juvenile densities twice those in the control reaches. We conducted habitat use surveys in the spring of 2003, 2005, 2008 and 2010 to evaluate the affect of the project on juvenile Chinook densities. Our study focused on Phases 3A and 3B, which were completed in 2002 and 2007 respectively. The survey area included two restoration phases and two control reaches. We estimated Chinook numbers from underwater snorkel observations. We compared fish densities by reach, restored versus unrestored, incorporated habitat features and presence of adjacent riparian vegetation, using ANOVA and pairwise comparisons. Overall, juvenile densities were lower in restoration areas than in controls. While high juvenile densities were sustained in Phase 3A, Phase 3B would benefit from additional instream work. Phase 3B had significantly lower juvenile densities than other reaches in part because performance of revetment rootwads in 3B declined. We examined how differences in design, implementation or evolution of the rootwads may result in differences in habitat structure, complexity, water velocity and sustainability. The 3B rootwads and poor quality habitats would be improved by adding suitable substrate, submerged shoreline vegetation, and additional woody debris. This monitoring will be useful in adapting this and future projects.

Brown, R., S. Greene, et al. (1996). An evaluation of the effectiveness of fish salvage operations at the intake to the California Aqueduct, 1979-1993. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, American Association for the Advancement of Science AAAS: 497-518.

We describe the results of the last 14 years of experience gained in operating a large fish protection facility at the intake to the California Aqueduct in the Sacramento-San Joaquin Delta. The Department of Water Resources constructed the behavioral barrier (louver) system in the late 1960s for a maximum flow of about 180m3/s. The facilities have since been modified extensively, and the capacity has been increased to about 290m3s. Although more than 40 species of fish have been entrained in the diversion, we focus on the facilities' effectiveness at screening Chinook salmon. Screening efficiency varies with fish length, ranging from 70 to 80 percent of juvenile salmon about 100 m in length. Significant prescreen losses appear to be caused by subadult striped bass predation in a forebay in front of the fish facility. Small additional losses occur due to handling in the salvage process and when trucking the salvaged fish to Delta release sites about 40 kilometers from the intake. We also briefly describe mitigation measures to offset direct losses of Chinook salmon at the intake as well as actions that might be taken to reduce losses of these and other fish.

Brown, R. T. (2010). Description and potential benefits of the Delta Corridors Plan. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Brown, T. (2009). Phytoplankton Community Composition: The Rise of the Flagellates. IEP Newsletter. 22: 9.

Phytoplankton are an important component of the food web in the San Francisco Estuary. Species composition is also important; shifts in the phytoplankton community can have significant effects on the larger ecosystem. Recent increases in phytoplankton biomass in parts of the estuary have not been accompanied by corresponding increases in pelagic species. This suggests that species composition of the phytoplankton may be playing a role. Phytoplankton community composition was examined at several long-term monitoring stations in the estuary. Changes in community composition were significant, and primarily due to just a handful of taxa. Historically, the delta has been dominated by diatoms, but some areas are now dominated by flagellate taxa. The implications of these changes are discussed, and areas of further study identified.

Brown, T., and others (2009). Water quality conditions in the Sacramento-San Joaquin Delta and Suisun and San Pablo Bays during 2007. Water Quality Conditions in the Sacramento-San Joaquin Delta and Suisun and San Pablo Bays. Sacramento, CA, California Department of Water Resources: 173 pp.

Brown, T. (2010). 2008 Phytoplankton Community Composition. IEP Newsletter. 23: 5.

Brown, T., and others (2010). Water quality conditions in the Sacramento-San Joaquin Delta and Suisun and San Pablo Bays during 2008, California Department of Water Resources.

This report summarizes the results of water quality monitoring and special studies conducted by the Environmental Monitoring Program (EMP) within the Sacramento-San Joaquin Delta and Suisun and San Pablo bays (the upper San Francisco Estuary) during calendar year 2008. This monitoring is mandated by Water Right Decision 1641 (D-1641) and this report is being submitted to fulfill the reporting requirements of this decision.

The EMP monitored water quality using a protocol implemented in 1996. Under this monitoring protocol, 13 sampling sites—2 of which were added after 1996—representing 8 regions of the upper San Francisco Estuary (Estuary) were monitored for 15 physical and chemical water quality parameters. The results gathered from the sampling of these 15 parameters are described in this report. Parameters such as water temperature, secchi disk depth, dissolved oxygen concentration, specific conductance, dissolved inorganic nitrogen, orthophosphate, and volatile suspended solids were within their historical range. Measured parameters exhibited seasonal variation, as well as changes in response to significant rainfall events, or changes in flow rates. In addition to monitoring physical and chemical water quality parameters, biological sampling was conducted to monitor the productivity and community composition of phytoplankton, zooplankton and benthic communities.

Chlorophyll a is the principal photosynthetic pigment and is common to all phytoplankton. Chlorophyll a is thus used as a measure of phytoplankton biomass. Samples for chlorophyll a and phytoplankton were taken at 13 sampling sites in the Estuary. Chlorophyll a concentrations for 2008 showed seasonal patterns and were generally below 10 µg/L for most regions and concentrations ranged between 0.76 µg/L and 226.42 µg/L throughout the Estuary. Phytoplankton samples were collected using a submersible pump from 1 meter below the water’s surface. All organisms collected in 2008 fell into twelve categories: centric diatoms, cyanobacteria, unidentified flagellates, green algae, pennate diatoms, cryptomonads, euglenoids, haptophytes, chrysophytes, unknown genus, dinoflagellates and synurophytes. Of the twelve groups identified, centric diatoms, cyanobacteria, unidentified flagellates, chrysophyte flagellates, cryptophyte flagellates, green algae and pennate diatoms constituted 96.88% of the organisms collected.

Zooplankton were collected at 22 sampling sites in the estuary. The introduced Hyperacanthomysis longirostris (formerly Acanthomysis bowmani) and the Neomysis kadiakensis/japonica complex remained the two most abundant mysids, followed by the native Alienacanthomysis macropsis and Neomysis mercedis. Pseudodiaptomus forbesi was the most common calanoid copepod followed by the native Acartia spp. The introduced Acartiella sinensis was third most abundant. The three most common cyclopoid copepods remained the introduced Limnoithona tetraspina and Oithona davisae, followed by the native Acanthocyclops vernalis. The three most abundant cladocerans were Bosmina spp., Diaphanosoma spp. and Daphnia spp. Synchaeta spp. was the most common rotifer, followed by Polyarthra spp. and Keratella spp. Limnoithona tetraspina continued to be the most abundant zooplankton in the estuary.

Benthic monitoring was conducted at 10 stations throughout the Estuary to document substrate composition and the distribution, diversity and abundance of benthic organisms within the
Estuary. The benthic community was determined to be a diverse assemblage of organisms including annelids (worms), crustaceans, aquatic insects and molluscs (clams and snails). All organisms collected during 2008 fell into nine phyla: Annelida, Arthropoda, Chordata, Cnidaria, Mollusca, Nemertea, Nematoda, Phoronida and Platyhelminthes. Of these nine phyla, Annelida, Arthropoda and Mollusca constituted 99.1% of the organisms collected during the study period. Ten species in these phyla represent 82.8% of all organisms collected during this period.

The EMP also conducted a series of special studies to monitor dissolved oxygen (DO) levels within the Stockton Ship Channel during the late summer and early fall of

2008. The studies were conducted to determine if DO levels dropped below Central Valley Regional Water Quality Control Board and State Water Resources Control Board water quality objectives (5.0 mg/L and 6.0 mg/L, respectively) established for the channel. Monitoring was conducted biweekly from June 16 to November 25 from Prisoner's Point in the central Delta to the Stockton Turning Basin at the eastern terminus of the channel. Monitoring results showed DO concentrations varied little between regions within the channel (not including the turning basin), with an overall range of 4.5 to 10.3 mg/L at the surface and 4.3 to 9.8 mg/L at the bottom.

Brunell, M. (2010). Low turbidity and high water quality correlated with Microcystis in the south Delta. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Brusati, E. D. and E. D. Grosholz (2006). "Native and Introduced Ecosystem Engineers Produce Contrasting Effects on Estuarine Infaunal Communities." Biological Invasions 8(4): 683-695.

Cordgrasses in the genus Spartina are good examples of ecosystem engineers that modify habitat structure in estuaries throughout the world. In San Francisco Bay, California, USA, marshes containing native California cordgrass (Spartina foliosa) are being invaded by a hybrid (S. alterniflora x S. foliosa) formed after introduction of S. alterniflora. This study compared vegetation, sediment structure, and infaunal invertebrates in native and invaded marshes. We hypothesized that differences in the physical structure between S. foliosa and hybrid Spartina would be reflected in differences in density, biomass, diversity, and taxonomic composition of infauna. Hybrid Spartina modifies habitat structure more than S. foliosa by producing taller stems, and greater plant biomass both above- and belowground while occupying a much wider tidal range, thereby transforming open mudflats to a vegetated habitat. In general, S. foliosa areas contained significantly higher densities of benthic infauna than adjacent mudflats, while hybrid Spartina areas never contained greater infaunal densities than mudflats. This is because S. foliosa produces a moderate level of structure that can facilitate benthic invertebrates, whereas hybrid Spartina produces so much structure, particularly belowground, that it actually excludes invertebrates. Therefore, we suggest that these two closely related species both act as ecosystem engineers, but with opposing effects on invertebrate communities.

Brusati, E. D. and E. D. Grosholz (2007). "Effect of native and invasive cordgrass on Macoma petalum density, growth, and isotopic signatures." Estuarine, Coastal and Shelf Science 71(3-4): 517-522.

Ecosystem engineers can influence community and ecosystem dynamics by controlling resources, modifying the flow of energy or biomass, or changing physical characteristics of the habitat. Invasive hybrid cordgrass (Spartina alternifloraxSpartina foliosa) is an ecosystem engineer in salt marshes in San Francisco Bay, California, U.S.A. that raises intertidal elevations and may be either increasing C sub(4) plant carbon input into food webs or tying up carbon in a form that is not usable by consumers. A manipulative experiment compared abundance, growth, and stable isotope (delta super(1) super(3)C and delta super(1) super(5)N) composition of the clam Macoma petalum (=M. balthica) among native marsh, hybrid Spartina, and mudflats in central San Francisco Bay. We found higher densities (individuals m super(-) super(2)) of M. petalum on mudflats compared to either native or hybrid Spartina (p<0.001). Macoma petalum shell growth was significantly greater in mudflats than in either vegetation type in 2002 (p=0.005) but not 2003. Differences in shell growth between native and hybrid Spartina were not significant. Stable isotope results showed differences between habitats in delta super(1) super(3)C but not delta super(1) super(5)N. Carbon signatures of M. petalum placed in Spartina were much more depleted than the isotopic signature of Spartina. Neither native nor hybrid Spartina appears to be a significant carbon source for M. petalum in San Francisco Bay, and we found no evidence that hybrid Spartina contributes carbon to M. petalum beyond what is provided by S. foliosa, despite the hybrid's much greater biomass. Our results show that loss of mudflat habitat, rather than increased input of C sub(4) carbon, is the greatest effect of the invasion of hybrid Spartina on M. petalum.

Bryant, M., and K. Souza (2004). Summer Townet Survey and Fall Midwater Trawl Survey Status and Trends. IEP Newsletter. 17: 4.

Buchanan, P. A. (2003). Specific-Conductance, Water-Temperature, and Water-Level Data, San Francisco Bay, California, Water Years 2001-1002. IEP Newsletter. 16: 6.

Buchanan, P. A. (2009). Specific-Conductance and Water-Temperature Data, San Francisco Bay, California, for Water Years 2006, 2007. IEP Newsletter. 22: 6.

Buchanan, P. A. and C. A. Ruhl (2000). Summary of suspended-solids concentration data, San Francisco Bay, California, Water Year 1998. Sacramento, CA, U.S. Geological Survey.

Buchanan, P. A. and D. H. Schoellhamer (1995). Summary of suspended-solids concentration data, San Francisco Bay, California, Water Years 1992 and 1993. Sacramento, CA, U.S. Geological Survey.

Buchanan, P. A. and D. H. Schoellhamer (1996). Summary of suspended-solids concentration data, San Francisco Bay, California, Water Year 1995. Sacramento, CA, U.S. Geological Survey.

Buchanan, P. A. and D. H. Schoellhamer (1998). Summary of suspended-solids concentration data, San Francisco Bay, California, Water Year 1996. Sacramento, CA, U.S. Geological Survey.

Buchanan, P. A. and D. H. Schoellhamer (1999). Summary of suspended-solids concentration data, San Francisco Bay, California, Water Year 1997. Sacramento, CA, U.S. Geological Survey.

Buchanan, P. A., D. H. Schoellhamer, et al. (1995). Summary of suspended-solids concentration data, San Francisco Bay, California, Water Year 1994. Sacramento, CA, U.S. Geological Survey.

Buchanan, R., J. Skalski, D. Vogel, and P. L. Brandes (2010). Survival and route selection of juvenile chinook salmon in the southern Sacramento-San Joaquin River Delta, 2009. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Chinook salmon smolts have low survival through the Sacramento-San Joaquin River Delta. Identifying management actions to improve survival requires detailed information on the migration routes salmon take through the Delta, and on reaches with high mortality. To address these questions, in 2009, 933 juvenile hatchery fall/spring Chinook salmon smolts were tagged with HTI micro acoustic tags and released in the San Joaquin River approximately 12 miles upstream of the confluence with Old River, as part of the Vernalis Adaptive Management Program. Tagged smolts were monitored at 18 fixed-site acoustic receivers located throughout the south Delta. Acoustic-tag detections were analyzed with a release-recapture model to estimate route entrainment probabilities at the head of Old River and survival probabilities in key reaches of the San Joaquin and Old rivers. Mortality from the release point to the head of Old River was estimated to be high (0.55, SE = 0.02) in 2009. Approximately half (53%, SE=3%) of the fish that arrived at Old River entered that river. Of those fish, an estimated 11.5% (SE=2.3%) subsequently arrived at the water export facilities, and less than 1% were detected downstream of the facilities. For the smolts remaining in the San Joaquin River, estimated survival was lowest from the Stockton Navy Bridge to Turner Cut (0.10, SE=0.03), but was moderately high through the city of Stockton (0.78, SE = 0.04). Overall, estimated survival through the south Delta was 0.06 (SE=0.01). The low survival may be related to high predation pressure from non-native fishes in key locations in the San Joaquin and Old rivers, possibly intensified by low flow conditions. Our information can be used to inform management on the roles of flow and reach specific survival on the passage of juvenile salmon migrating through the south Delta from the San Joaquin basin.

Buck, K., B. Foli, S. Ussher, and K. Barbeau (2010). Copper speciation in the San

Francisco Bay Delta and Estuary: Evaluating current and future likelihood of copper toxicity events in a perturbed ecosystem. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Surface seawater samples were collected on 19 November 2008 from North San Francisco Bay Delta and Estuary in collaboration with the U.S. Geological Survey Water Quality of San Francisco Bay monitoring program. Additional samples were collected the following day from the San Joaquin River (Mossdale boat launch) and Suisun Slough (Suisun City boat launch). Trace metal clean protocols were employed throughout sampling and sample processing to avoid sample contamination. All samples were filtered through 0.4 µm pore size polycarbonate track-etched (PCTE) membrane filters in a clean lab. Competitive ligand exchange-adsorptive cathodic stripping voltammetry (CLE-ACSV) was used to determine total dissolved copper and copper speciation, and to evaluate the potential for copper toxicity in these waters. Graphite furnace atomic absorption spectrometry (GFAAS) was used to measure leachable particulate copper and zinc concentrations from a 25% acetic acid leach of suspended sediments collected on sample filters. Concentrations of leachable particulate copper and zinc, as well as dissolved copper, were elevated in all estuarine samples above adjacent coastal seawater. However, complexation by strong organic ligands dramatically reduced the bioavailability of dissolved copper with high concentrations of weaker organic ligands buffering against copper toxicity at increasing copper concentrations.

Buck, K. N. and K. W. Bruland (2005). "Copper speciation in San Francisco Bay: A novel approach using multiple analytical windows." Marine Chemistry 96(1-2): 185-198.
Dissolved copper speciation and total dissolved copper concentrations were determined at six San Francisco Bay sites in January and March of 2003. Multiple analytical windows were incorporated into an established competitive ligand exchange-adsorptive cathodic stripping voltammetry (CLE-ACSV) method, which employs salicylaldoxime (SA) as the added competitive ligand for speciation analyses. The titration results were integrated into [Cu sub(T) super(*)] versus log [Cu super(2) super(+)] plots, combining data from each of the different competing ligand concentrations and providing a powerful approach to visually interpret the variation in [Cu super(2) super(+)] as the natural Cu-binding ligands in the sample are titrated over a wide range of [Cu sub(T)]. In addition, the data for different analytical windows were interpreted with Langmuir and Scatchard linearization techniques to estimate natural Cu-binding ligand concentrations [L sub(i)] and conditional stability constants K sub(C) sub(u) sub(L) sub(i) sub(,) sub(C) sub(u) sub(@)u sub(2) sub(@)u sub(+) super(c) super(o) super(n) super(d). All results indicate that ambient ligand concentrations exceed total dissolved copper concentrations at each site, with dissolved copper greater than 99.9% complexed by the strong copper-binding L sub(1) ligand class. The [Cu super(2) super(+)] does not exceed 10 super(-) super(1) super(3) M at any site, a concentration sufficiently below the toxicity threshold for microorganisms. Thus, the excess of strong Cu-binding ligands appears to effectively buffer free Cu super(2) super(+) at low concentrations and the existing levels of copper do not impair San Francisco Bay.

Buck, K. N., M. C. Lohan, et al. (2007). "Dissolved iron speciation in two distinct river plumes and an estuary: Implications for riverine iron supply." Limnology and Oceanography 52(2): 843-855.
Dissolved iron (Fe) speciation in the Columbia River plume, the San Francisco Bay plume, and the Columbia River estuary was investigated using competitive ligand exchange-adsorptive cathodic stripping voltammetry (CLE-ACSV) with the added ligand salicylaldoxime. A stronger L sub(1)-type Fe-binding ligand class was measured in all surface samples, and in the Columbia River estuary. A weaker L sub(2)-type ligand class was present in the far-field Columbia River plume and the San Francisco Bay plume but was not observed in the low-salinity (S = 1.4-22.5) waters of the near-field Columbia River plume or estuary. Concentrations of total dissolved Fe were correlated with the concentrations of the stronger L sub(1)-type ligand in nonestuarine (S > 13) surface samples. Leachable particulate (>0.4 mu m) Fe concentrations in the Columbia River plume were measured to supplement existing data from the San Francisco Bay plume. There is a large concentration of readily leachable particulate Fe in the two plumes, yet it is the

concentration of ambient L sub(1)-type ligands that appears to dictate the concentration of dissolved Fe in these waters and, consequently, the supply of dissolved Fe to neighboring coastal waters. The correlation between dissolved Fe and L sub(1) ligand concentrations in both plume waters, as well as in California Current and upwelled surface waters, suggests that this relationship will persist in other coastal environments and should be considered when evaluating and modeling coastal Fe cycling and supply.

Buck, K. N., J. R. M. Ross, et al. (2007). "A review of total dissolved copper and its chemical speciation in San Francisco Bay, California." Environmental Research 105(1): 5-19.

Following basin-wide contamination from industrial emissions and urban development, total dissolved copper concentrations in some regions of San Francisco Bay have exceeded national and state guidelines for water quality. In the face of dramatic improvements in wastewater treatment and point source control, persisting elevated dissolved copper concentrations in the Bay have prompted multiple studies and extensive monitoring of this estuary since 1989. Statistical analyses of monitoring data show that total dissolved copper concentrations have declined in the North (by 17%) and South (29%) San Francisco Bay as well as in the Southern Sloughs (44%) from 1993 to 2001. Concentrations remain elevated in the farthest reaches of the Bay (Delta and Estuary Interface), and in the Central Bay. Dissolved copper concentrations throughout the Bay have also been positively correlated (r=0.632, P<0.0005, n=598) with dissolved organic matter, supporting results from complimentary chemical speciation studies which indicate that high-affinity copper-binding organic ligands dominate the chemical speciation of dissolved copper in the Bay. These organic ligands typically bind>99.9% of the dissolved copper, effectively buffering the system against small changes in dissolved copper concentrations, and maintaining free Cu super(2) super(+) concentrations well below the toxicity threshold of ambient aquatic microorganisms. In response to these findings, site-specific water quality criteria for dissolved copper concentrations are now being developed by the Regional Water Quality Board to provide a more appropriate standard for copper toxicity in the Bay-one based on its chemical speciation and bioavailability.

Bugg, R., T. Strange, and J. Davidge (2010). Biohaven® Floating Islands to enhance the ecology of the Sacramento-San Joaquin Delta and San Francisco Bay. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Biohaven® Floating Islands are composed of spun, recycled polyester plastic (types 1 and 2) or of natural fibers (e.g. coir) and can be used to address several of the key problems of the Sacramento-San Joaquin Delta. Natural floating islands (also termed batteries, floatons, sudds, or tussocks) still occur in parts of the Delta, arising through de-lamination of peat and subsequent colonization by vascular plants. Large Biohaven© Floating Islands (0.5 acre and 1 acre) have been launched in Siskiyou lakes and are providing viable nesting sites for Caspian tern. Smaller Biohaven® Floating Islands have been used to simulate natural floating islands or submerged vegetated undercut banks in lakes and streams, providing habitat for salmonid and other fishes. A range of California native riparian and emergent plants can readily be established and maintained. Potential functions of artificial floating islands include providing: (1) spot habitat for salmonid fishes in flooded tracts and main channels; (2) macrophyte-based primary productivity to support littoral and pelagic organisms of interest; (3) floating wetlands for wastewater treatment facilities to reduce ammonium and phosphorus discharges; (4) nesting and roosting sites for birds and haul-out sites for marine mammals; and (5) buffers for managing tidal, fluvial, wave, and wake energy. A key advantage of floating islands over conventional re-vegetation of levees is that floating islands will not impair the structural integrity of levees, and can be easily towed to new locations as needed.

Bumgardner, J., C. Malone, L.F. Walker, and R.F. Shanks (1993). "Use of Monte Carlo techniques to assess POTW compliance with EPA water quality criteria for heavy metals." Water Environment Research 65(5): 674-678.

This paper presents the results of a study (Larry Walker Associates, 1990)

to determine the nature of additional controls necessary for the Sacramento Regional Wastewater Treatment Plant (Regional Plant) to comply with the numeric water quality objectives for metals recently adopted by the State of California. In addition, the impact of Regional Plant effluent on Sacramento River metals concentrations is examined, and the costs of compliance with the new objectives are estimated. Monte Carlo techniques are used to determine the ability of the Regional Plant to achieve the metals objectives and the effects of treatment plant discharge on receiving water metal concentrations. Frequency distributions of advanced treatment efficiencies, such as lime precipitation and reverse osmosis, are used to simulate effluent concentration reductions that are potentially achievable. The costs associated with the additional treatment required to meet objectives are estimated using published cost estimates for advanced treatment plants of similar size. Results show that currently, the Regional Plant does not meet objectives for cadmium, copper, mercury, and zinc. Furthermore, the additional treatments evaluated would not completely eliminate violations of the copper and mercury objectives.

Burau, J. R. (1998). Results from the hydrodynamic element of the 1994 entrapment zone study in Suisun Bay. Report of the 1994 Entrapment Zone Study. W. J. Kimmerer. Sacramento, CA, Interagency Ecological Program for the San Francisco Estuary. 56: pp. 13-62.

Burau, J. R. (2010). Muddy waters: A discussion of recent turbidity measurements in the Delta. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Burau, J. R. and R. T. Cheng (1989). "A general method for generating bathymetric data for hydrodynamic computer models."

Burnett, R., A. Young, and J. Souza (2010). Restoring riparian habitat on altered floodplains by integrating vegetation and avian monitoring. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Much of the information on riparian habitat restoration in the Central Valley is based on in-tact floodplains with productive soils. The Lower Clear Creek Floodway Rehabilitation Project in Shasta County, California, was designed to restore the stream channel and floodplains that have been severely impacted by aggregate and dredger gold mining and altered flood flows due to Whiskeytown Dam. Floodplains were re-constructed with coarse dredge tailings and floodplain deposits placed on top of an undulating clay pan with a perched water table. Original restoration sites were designed and planted using evenly spaced cuttings of riparian trees (e.g. willows and cottonwood) on topographically uniform surfaces. This approach has been successful in establishing these cuttings, but the low productivity of the coarse soils coupled with sediment-starved post-restoration flood flows has limited the amount of natural recruitment. Monitoring results show these sites are only being used by a limited number of bird species primarily due to a lack of a dense understory typical of early successional riparian habitat. Integrating monitoring results from vegetation and avian monitoring has resulted in changes to restoration design in subsequent phases. Based on these results the most recent phase of restoration has increased the extent of features that have proven successful in prior phases such as save areas of mature vegetation, extensive scour channels, and backwaters. In addition, site assessments are being conducted post-floodplain construction in order to revise planting methods to provide riparian vegetation that provides the necessary nesting habitat for birds. By integrating avian and vegetation monitoring we have been able to adapt restoration designs to ensure that the needs of a suite of riparian-dependent species are being met. The Clear Creek restoration project has provided important information for floodplain restoration using dredger tailings and an effective model of monitoring and adaptive feedback.

Burns, J. W. (1975). The upper Sacramento River: Its problems and a plan for its protection, California Department of Fish and Game.

Burns, M., K. Gandhi, T. Hunziker, and T. Hamaker (2010). The larinier fish passage:

Implementing “new” technology to facilitate steelhead fisheries restoration in Alameda Creek Flood Control Channel. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Steelhead restoration efforts within the Alameda Creek Watershed initially targeted Rubber Dam 2, which is owned and operated by Alameda County Water District, for removal. However, a hydraulic analysis of the creek system indicated that the dam’s concrete foundation provides channel stabilization and grade control and therefore cannot be removed. The concrete foundation creates a three foot grade drop within the channel, which causes delay for steelhead migrating through the flood control channel. Traditional fish passage technologies were evaluated and eliminated due to the low–flow design requirement of 20 to 100 cubic feet per second and ephemeral characteristics of the creek. Non-traditional fish passage technologies were also evaluated. The Super-Active Baffle Fish Passage, also referred to as the Larinier Fish Passage, was identified as a possible technology. This passage is commonly used in France, England, and Wales but there are no known installations in North America. The baffles within the Larinier Fish Passage create helical currents that rapidly dissipate energy, thus decreasing the flow velocity throughout the baffled area. This drop in velocity allows fish to pass through the baffled area if their ability to swim, which is species specific, matches the passage design. A hydraulic model was developed to confirm that the Lariner Fish Passage could be designed to meet the flow regimes in Alameda Creek Flood Control Channel. These results, along with empirical data from the installations in Europe, were sufficient to gain approval to install the Larinier Fish Passage from stakeholders and regulatory agencies. Design and construction was completed in October 2009. The Larinier Fish Passage is a “new” fish passage concept that can be utilized to facilitate steelhead fisheries restoration. It has the potential to be particularly effective in California, where ephemeral flows are common.

Byrne, R., B. L. Ingram, et al. (2001). "Carbon-isotope, diatom, and pollen evidence for late holocene salinity change in a brackish marsh in the San Francisco Estuary." Quaternary Research 55(1): 66-76.
Analysis of diatoms, pollen, and the carbon-isotopic composition of a sediment core from a brackish marsh in the northern part of the San Francisco Estuary has provided a paleosalinity record that covers the past 3000 yr. Changes in marsh composition and diatom frequencies are assumed to represent variations in freshwater inflow to the estuary. Three periods of relatively high salinity (low freshwater inflow) are indicated, 3000 to 2500 cal yr B.P., 1700 to 730 cal yr B.P., and ca. A.D. 1930 to the present. The most recent period of high salinity is primarily due to upstream storage and water diversion within the Sacramento-San Joaquin watershed, although drought may also have been a factor. The two earlier high-salinity periods are likely the result of reduced precipitation. Low salinity (high freshwater flow) is indicated for the period 750 cal yr B.P. to A.D. 1930. Copyright 2001 University of Washington.

Caffrey, J. M., D.E. Hammond, J.S. Kuwabara, L.G. Miller, and R.R. Twilley (1996). Benthic processes in South San Francisco Bay: The role of organic inputs and bioturbation. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science: 425-442.

Caffrey, J. M., J.E. Cloern, and C. Grenz (1998). "Changes in production and respiration during a spring phytoplankton bloom in San Francisco Bay, California, USA: Implications for net ecosystem metabolism." Marine Ecology Progress Series 172: 1-12.
We present results of an intensive sampling program designed to measure weekly changes in ecosystem respiration (oxygen consumption in the water column and sediments) around the 1996 spring bloom in South San Francisco Bay, California, USA. Measurements were made at a shallow site (2 m, where mean photic depth was 60% of the water column height) and a deep site (15 m, mean photic depth was only 20% of the water column). We also estimated phytoplankton primary production weekly at both sites to develop estimates of net oxygen flux as the sum of pelagic production (PP), pelagic respiration (PR) and benthic respiration (BR). Over the 14 wk period from February 5 to May 14, PP ranged from 2 to 210, PR from 9 to 289, and BR from 0.1 to 48 mmol O2 m-2 d-1, illustrating large variability of estuarine oxygen fluxes at the

weekly time scale. Pelagic production exceeded total respiration at the shallow site, but not at the deep site, demonstrating that the shallow domains are net autotrophic but the deep domains are net heterotrophic, even during the period of the spring bloom. If we take into account the potential primary production by benthic microalgae, the estuary as a whole is net autotrophic during spring, net heterotrophic during the nonbloom seasons, and has a balanced net metabolism over a full annual period. The seasonal shift from net autotrophy to heterotrophy during the transition from spring to summer was accompanied by a large shift from dominance by pelagic respiration to dominance by benthic respiration. This suggests that changes in net ecosystem metabolism can reflect changes in the pathways of energy flow in shallow coastal ecosystems.

Caffrey, J. M., D. E. Hammond, et al. (1996). Benthic processes in south San Francisco Bay: the role of organic inputs and bioturbation. San Francisco Bay: The Ecosystem. J. T. Hollibaugh. San Francisco, AAAS: 425-442.

Cain, D. J., J.L. Carter, S.V. Fend, S.N. Luoma, C.N. Alpers, and H.E. Taylor (2000). "Metal exposure in a benthic macroinvertebrate, Hydropsyche californica, related to mine drainage in the Sacramento River." Canadian Journal of Fisheries and Aquatic Sciences 57(2): 380-390.

A biomonitoring technique was employed to complement studies of metal transport in the upper Sacramento River affected by acid mine drainage. Metals (Al, Cd, Cu, Fe, Hg, Pb, and Zn) were determined in a resident invertebrate, Hydropsyche californica (Insecta: Trichoptera), and streambed sediments (<62 mum) to assess metal contamination within a 111-km section of the river downstream of the mining area. Metals in H. californica also were interpreted to be broadly indicative of metal exposure in fish. Total Hg was determined in the whole body of the insect, whereas Al, Cd, Cu, Fe, Pb, and Zn were additionally separated into operationally defined cytosolic (used as an indicator of exposure to bioavailable metal) and particulate fractions. Total concentrations of Cd, Cu, Hg, Pb, and Zn in sediments were consistent with documented upstream sources of acid mine drainage. Metal distribution patterns in H. californica and sediments were generally consistent for Cd, Cu, and Pb but inconsistent for Hg and Zn. Concentrations in H. californica indicated that bioavailable Cd, Cu, Pb, and Zn was transported at least 120 km downstream of the mine sources. Zinc in H. californica was elevated, but unlike sediments, did not decrease downstream. Mercury in H. californica was not elevated.

Cain, D. J. and S. N. Luoma (1985). "Copper and silver accumulation in transplanted and resident clams (Macoma balthica) in south San Francisco Bay." Marine environmental research 15(2): 115-135.

Accumulation of Cu and Ag by soft tissues of the deposit-feeding clam Macoma balthica was less than half in clams transplanted to a contaminated area than in clams native to that area. During a period of tissue growth, the transplants retained 50% and 90%, respectively, of the net Cu and Ag accumulated, but loss of metals from soft tissue by the resident population equalled net accumulation. Copper accumulation in the transplants did not occur during some periods when increases in the metal body burden of the resident population indicated that environmental exposures were high. The difference in metal accumulation of the two groups of clams may be the result of past environmental exposures. The results illustrate some limitations of using transplants as indicators of pollution events or of pollutant impact upon resident populations.

Cain, D. J. and S. N. Luoma (1986). "Effect of seasonally changing tissue weight on trace metal concentrations in the bivalve Macoma balthica in San Francisco Bay." Marine Ecology Progress Series 28(3): 209-217.

The influence of seasonal changes in the weight of soft tissues on temporal fluctuations in tissue concentrations of Cu and Zn was examined in 4 populations of the clam Macoma balthica sampled in San Francisco Bay for a period of 2 to 5 yr. Fluctuations in metal concentration expected from changes in tissue weight between sampling dates were estimated by assuming that whole body metal burden was constant during the sampling interval. Comparison of estimated and actual metal concentrations showed that the degree to which fluctuations in trace metal concentrations were driven by weight changes differed considerably among stations,

among years at a single station, and between metals.

Cain, D. J. and S. N. Luoma (1990). "Influence of seasonal growth, age, and environmental exposure on Cu and Ag in a bivalve indicator, Macoma balthica , in San Francisco Bay." Marine Ecology Progress Series. 60: 1-2.
        Temporal and spatial variations in Cu and Ag in the deposit-feeding clam Macoma balthica and in surficial sediments were analysed at 8 stations in San Francisco Bay at near-monthly intervals for periods ranging from 3 to 10 yr during 1977 to 1986. Strong seasonal variations in metal concentrations of M. balthica were associated with seasonal variations in soft tissue weight. Aperiodic fluctuations in metal concentrations appeared to be driven by changes in metal content of the soft tissues. Metal content of clams of standard shell length was less variable than tissue metal concentrations, and generally followed changes in the concentrations of Cu and Ag in the sediments. Correlations between metal content and sediment concentrations were improved when content was standardized to age rather than shell length.

Calhoun, A. J. (1952). "Annual migrations of California striped bass." California Fish and Game 38: 391-403.

California Department of Fish and Game (CDFG) (1987). Factors affecting striped bass abundance in the Sacramento-San Joaquin River system. Sacramento CA, Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary: 149 pages plus appendices.

California Department of Water Resources (CDWR) (1994). California Central Valley unimpaired flow data (October 1020 through September 1992). Sacramento, California Department of Water Resources: 54.
        This report outlines the procedure DWR uses to determine unimpaired Delta outflow. It explains the
methods and assumptions used for estimating the unimpaired flow for 24 sub-basins in the Central Valley.
The unimpaired flow to the Delta is the sum of the unimpaired flow estimates of the 24 sub-basins. The
Delta region is one of the 24 sub-basins.

Callaway, J., E. Borgnis, G. Turner, C. Milan, and J. Drexler (2010). Sediment accretion and carbon sequestration in San Francisco Bay salt and brackish tidal wetlands. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
        We are measuring rates of sediment accretion and carbon sequestration in eight natural salt and brackish tidal wetlands in the San Francisco Bay Estuary. This research is motivated by the need understand long-term stability of tidal wetlands in the face of sea-level rise and to provide background data to predict long-term rates of carbon sequestration in restored wetlands within the Estuary, as California is currently evaluating the possibility of assigning carbon trading credits for wetland restoration. Our sites cover South SF Bay (three sites), North SF Bay (three sites) and Suisun Bay (two sites), representing the geographical range of the Estuary as well as serving as analogs for long-term carbon sequestration in restored wetlands across the Estuary. We are collecting six cores at each site (two transects with three stations each). This approach is designed to allow us to identify spatial variation both within and among wetlands in the Estuary. Cores are being dated using 137Cs and 210Pb profiles. Long-term sediment accretion rates from the South Bay sites have ranged primarily from 0.3 to 0.9 cm/yr, while North Bay sites are closer to 0.1 to 0.3 cm/yr, leaving most sites close to or slightly above current rates of sea-level rise. However, many sites could experience increased rates of inundation under predicted rates of future sea-level rise, potentially leading to long-term conversion of wetlands to open-water or mudflats. Carbon sequestration rates have averaged approximately 50 g/m2/yr over the 100 year time span of 210Pb and are slightly higher for 137Cs-based dates. One South SF Bay site has accumulated over 100 g/m2/yr C; however, most of the high rates of sequestration are based on 137Cs dating.

Callaway, J., V. T. Parker, L. Schile, E. Herbert, E. Borgnis, and L. Porcella (2010). Sediment dynamics at the island ponds: indications from early salt pond restoration. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Many potential wetland restoration sites, including the South Bay salt ponds, have subsided substantially; if levees are breached, significant sediment accumulation will be necessary to reach threshold elevations for plant establishment. In order to evaluate the early phases of salt pond restoration, we monitored sediment dynamics at the Island Ponds, with spatially intensive sampling at Pond A21 (westernmost pond) and less intensive sampling at A20 and A19 (easternmost). We measured vertical rates of sedimentation using both the gypsum layer that is present across these ponds as a sediment marker and sediment pins. Measurements were made at 1, 3, and 6 mo and then annually at A21 and annually at A20 and A19. Over the first year, we measured mass-based rates of short-term sedimentation at A21, using a modified filter-paper method over two-week tidal periods every two months. We also monitored plant recruitment through general observations at the ponds. There has been substantial sediment accumulation within Pond A21 since breaching in 2006, with approximately 12-14 cm of sediment accumulating over the first year in most of the southern half of A21, and variable but lower rates in the northern half of the pond. Short-term, mass-based accumulation rates over the first year reflected similar spatial variability across A21. Sedimentation rates at A21 decreased in the second and third year but still were high compared to well-established marshes. On the broader spatial scale, sediment accumulation rates decreased from the west to east, with high rates at A21 and A20 and the lowest rates at A19 across all years. Plant recruitment was highest at Pond A21; in year two, recruitment within A21 was patchy with plants growing primarily along channel and barrow ditch edges. Substantially more vegetation recruited in year three at Pond A21, but vegetation remains very patchy at A20 and A19.

Callaway, J. C. (2005). "The challenge of restoring functioning salt marsh ecosystems." Journal of Coastal Research Sp. Iss. 40: 24-36.
Substantial improvements have been made in the restoration of coastal salt marshes over the last decade; however, many challenges remain. Some opportunities for improving restoration efforts include: I. Increasing our understanding of the development of restored salt marsh ecosystems over time, especially in comparison to natural marsh development; and identifying the limiting factors that restrict the development of restored salt marshes. If. Considering the role of plant species diversity in restored salt marshes. Recent research at Tijuana Estuary has demonstrated that there is a significant effect of plant species diversity on the development of ecosystem functions in a restored salt marsh; further study of these effects is warranted in other salt marsh ecosystems. III. Evaluating the link between physical heterogeneity and ecosystem function. Small-scale changes in physical factors, such as elevation or hydrology, are likely to have substantial effects on the development of ecosystem function in restored salt marshes, and these factors should be considered in restoration design. IV. Addressing the potential impacts of exotic plants within restored marshes. Exotic species remain a substantial problem in many restored ecosystems; better efforts are needed to identify appropriate methods to control exotic plants. V. Incorporating scientific approaches into restoration efforts. Rigorously designed scientific experiments that identify cause-effect relationships for the development of restored salt marshes could substantially improve the design, implementation, and monitoring of restoration projects.

Callaway, J. C. and M. N. Josselyn (1992). "The introduction and spread of smooth cordgrass (Spartina alterniflora) in south San Francisco Bay." Estuaries 15(2): 218-226.
Spartina alterniflora was first introduced into south San Francisco Bay in the 1970's. Since that time it has spread to new areas within the south bay and is especially well established at four sites. The spread of this introduced species was evaluated by comparing its vegetative and reproductive characteristics to the native cordgrass, Spartina foliosa . The characters studied were intertidal distribution, phenology, aboveground and belowground biomass, growth rates, seed production, and

germination rates. Spartina alterniflora has a wider intertidal distribution than S. foliosa and outproduced the native cordgrass in all aspects that were studied. These results indicate that the introduced species has a much better chance of becoming established in new areas than the native species, and once established, it spreads more rapidly vegetatively than the native species. Spartina alterniflora is likely to continue to spread to new areas in the bay and displace the native plant. In addition, this introduced species may affect sedimentation dynamics, available detritus, benthic algal production, wrack deposition and disturbance, habitat structure for native wetland animals, benthic invertebrate populations, and shorebird and wading bird foraging areas.

Callaway, J. C., V. Parker, et al. (2007). "Emerging Issues for the Restoration of Tidal Marsh Ecosystems in the Context of Predicted Climate Change." Madrono 54(3): 234-248.

There is currently a large regional effort to restore tidal marsh ecosystems in the San Francisco Bay-Delta Estuary involving the commitment of hundreds of millions of dollars and broad landscape-scale habitat manipulations. Although climate change has been on the horizon for many years, recent developments suggest that it must be taken seriously as a factor to be considered in future planning for marsh restoration efforts. Tidal marshes are vulnerable to changes in salinity and inundation rates, both of which will be affected by climate change. Restoration sites may be particularly vulnerable given unpredictable sediment inputs and newly established vegetation. Predicted shifts in snowmelt and altered runoff will change estuarine salinity patterns and could have large-scale impacts on marsh dominance, especially for freshwater marshes. Even relatively small salinity changes could lead to shifts in dominant species, with freshwater marshes being replaced by brackish marshes and brackish marshes converted to salt marsh communities. This will cause a reduction in overall estuarine plant diversity and productivity, with possible reverberations for the estuarine food web. Based on monitoring data from San Francisco Bay marshes, we predict that salinity will have a more immediate impact on tidal marsh vegetation than sea-level rise. However, sea-level rise poses a potentially greater long-term threat, depending on its rate, because the effects of inundation and a more persistent salinity regime could cause widespread marsh loss. If ice sheets in Antarctica and Greenland begin melting at rapid rates, inundation impacts could be catastrophic for coastal marshes. Given the magnitude of these potential changes, we urge the restoration and conservation management community to integrate these contingencies into adaptive management process and to join with the broader community in forging more flexible governance institutions that can respond effectively to large- scale uncertainties and trajectories as they unfold.

Callinan, K., L. Deanovic, and I. Werner (2010). An investigation on the sub-lethal effects of pesticides on Ceriodaphnia dubia. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Sub-lethal exposures to contaminants can alter ecosystems by reducing organism survival and compromising the ecological fitness of populations and species. In this study, Ceriodaphnia dubia (water fleas) were used as a model species to test for sub-lethal effects of pesticides on aquatic invertebrates. Organisms were exposed to a range of pesticide concentrations, above and below the lethal threshold, to test for mortality, reproductive success and swimming behavior. A 7-day toxicity test was conducted with bifenthrin, permethrin, cyfluthrin and copper. Brood sizes and mortality for all treatments and individuals (n=10) were recorded each day. Swimming behavior of surviving water fleas was analyzed at the completion of the test. Individuals were placed in cuvettes (8mm width) and filmed using a standard video camera for 90 seconds. Each of the videos were analyzed using Noldus EthoVision XT 6 video tracking software, based on dynamic subtraction at a rate of 16 frames per second. Total distance moved, average velocity, minimum and maximum velocity, time immobile, time mobile and time highly mobile were calculated. Data were analyzed using a one-way ANOVA and a Dunnetts test ($P < 0.05$). Preliminary results indicate that bifenthrin, permethrin, cyfluthrin and copper have significant effects on the survival and reproduction of C. dubia, but have varying effects on measures of swimming ability at sub-lethal concentrations. Previous studies, using acute exposures to similar chemicals, have inhibited swimming performance in C.

dubia, however, the current study uses chronic exposures whereby effects on swimming were inconsistent. These results are important, both for the assessment of environmental risk with regards to chronic, sub-lethal exposures to pesticides, and for the use of swimming behavior as a standardized monitoring tool to measure contaminant stress.

Campbell, E. A. and P. B. Moyle (1991). Historical and recent population sizes of spring-run chinook salmon in California. American Fisheries Society Proceedings, 1990 Northwest Pacific chinook and coho salmon workshop. Arcata, CA, Humboldt State University: 155-216.

Canuel, E. A. and J. E. Cloern (1996). Regional differences in the origins of organic matter in the San Francisco Bay ecosystem. Evidence from lipid biomarkers. San Francisco Bay: The Ecosystem. J. T. Hollibaugh. San Francisco, AAAS American Association for the Advancement of Science: 305-324.

Canuel, E. A., J. E. Cloern, et al. (1995). "Molecular and isotopic tracers used to examine sources of organic matter and its incorporation into the food webs of San Francisco Bay." Limnology and Oceanography 40: 67-81.

Multiple indicators (Chl a, C:N ratios, [delta super(13)C]POC, and two classes of lipid biomarker compounds - sterols and phospholipid ester-linked fatty acids) were used to evaluate spatial and temporal variations in the origin of particulate organic matter (POM) in the San Francisco Bay (SFB) estuary. Comparisons were made between the northern and southern subestuaries of SFB, as well as along the salinity gradient of northern SFB. Two sample types were collected - seston, which was used to characterize the bulk POM, and tissues of the suspension-feeding bivalve Potamocorbula amurensis - in order to evaluate the assimilable portion of the POM. Samples were collected around biological and physical events (phytoplankton blooms and freshwater inflow) thought to be the primary mechanisms controlling temporal variability in organic matter sources. Seston samples indicate that phytoplankton sources of POM are important throughout the entire SFB system, with additional inputs of organic matter from bacterial and terrestrial vascular plant sources delivered to the northern region. Analysis of biomarker compounds in P. amurensis tissues indicates that phytoplankton supply a large fraction of the assimilable carbon to clams throughout SFB, although isotopic analysis of clam tissues suggests that the origin of this reactive carbon varies spatially and that freshwater algae are an important source of reactive organic matter to clams living in northern SFB.

Carlson, P. R., J. L. Chin, et al. (2000). "Bedrock knobs, San Francisco Bay: Do navigation hazards outweigh other environmental problems?" Environmental & Engineering Geoscience 6(1): 41-55.

Three bedrock knobs (Arch, Harding, and Shag rocks) rise above the unconsolidated sediment of central San Francisco Bay to a water depth of less than -12 m (< -39.4 ft MLLW), These rocks are within the westbound vessel traffic area, and the northernmost, Harding Rock, is similar to 300 m (984 ft) from the two-way deep water traffic lane. The rocks pose a hazard to deep-draft vessels. Large ships with drafts deeper than -17 m (-55.8 ft) cross central San Francisco Bay bound for and returning from major port cities of the Bay estuary. Acoustic profiling data show that bedrock extends at a gentle to moderate slope away from the knobs. These data also show that two of the knobs, Harding and Shag, may be part of a bedrock ridge that extends to Alcatraz Island and perhaps southeast to Blossom Rock. The tops of these rocks should be lowered to a depth of -17 m (-55.8 ft), with a total volume of as much as 245,000 m(3) (320,460 yd(3)), at an estimated cost of nearly 27 million dollars, to eliminate the possibility that a tanker would strike one and rupture. A resulting large oil spill would likely cost many times more than the 10 million dollars needed to clean up a small 1996 spill. If the rocks were removed, local habitat for striped bass and other game fish would be altered, with potential negative impact on sport fishing. Currently, public officials are studying the benefits to the Bay environment of lowering the rock knobs.

Carlton, J. T. (1979). Introduced invertebrates of San Francisco Bay. San Francisco

Bay, the urbanized estuary. T. J. Conomos. San Francisco, CA, American Association for the Advancement of Science, Pacific Division: 427-444.
Almost 100 species of exotic marine invertebrates have been introduced into San Francisco Bay by man in the past 130 or more years. Primary mechanisms of introduction include transport of fouling, boring, and ballast-dwelling organisms by ships and epizoic and nestling invertebrates by commercial oysters. With the resolution of taxonomic problems and adequate exploration, many more introduced species may eventually be recognized from the Bay. The impact of this exotic fauna can be assessed in economic terms (pestiferous species, including shipworms and other borers) and in geologic terms (an introduced boring isopod has modified extensive portions of the bay shoreline by weakening clay and mud banks). The greatest effect, however, may be biological and ecological: the establishment of an introduced fauna as numerical and biomass dominants in many regions of the Bay, as revealed in both short- and long-term quantitative and qualitative studies. The modern-day significance of introduced species in fouling, benthic, and mudflat ecosystems in portions of San Francisco Bay raises questions as to the role of invertebrates prior to the mid-19th century both in the organic matter budget of the Bay-Estuary system and in the support of large native shorebird populations. Man’s extensive modifications of the Bay and concomitant creation of novel environmental conditions, the absence of a diverse native estuarine fauna, and competitive displacement have all played roles in the successful establishment of this impressively large and diverse introduced fauna.

Carlton, J. T. (1999). "Molluscan invasions in marine and estuarine communities." Malacologia 41(2): 439-454.
The distributions of many species of marine and estuarine mollusks have been altered dramatically by human movements over the past 2,000 and more years. Vectors have included vessels, mariculture, the aquarium trade, intentional or accidental releases into the wild, and canals. Most marine mollusk distributions are held to be "natural" prior to the 19th century, whereas mollusk distributions during or since the 19th century are held to be potentially subject to human modification. However, that pre-19th century invasions occurred is clear, suggesting that the antiquity of human-mediated mollusk introductions has been extensively underestimated. The Asian oyster Crassostrea gigas was introduced to Europe by the 1500s, the Northern Hemisphere mussel Mytilus may have arrived in the Southern Hemisphere by the early 1500s, and shipworms have similarly been widespread by shipping. A subset of 38 Northern Hemisphere introduced mollusks reveals distinct geographic patterns: 63% originate in the North Atlantic Ocean/Mediterranean area, while 37% originate in the North Pacific Ocean. Within the Atlantic Ocean, the western Atlantic is a significantly stronger donor area, accounting for 75% of those North Atlantic taxa that have dispersed globally. Similarly, the western Pacific Ocean is also a strong donor region, exporting 93% of all those originating in the Pacific. Ecologically, in San Francisco Bay, California, the introduced infaunal or near-surface bivalves Mya, Gamma, Venerupis, Musculista and Potamocorbula may be sufficiently abundant as to control water column productivity. The European snail Littorina littorea (Linnaeus, 1758) has had vast and complex impacts on intertidal hard and soft bottom communities from Canada to the mid-Atlantic America. In general, far more attention must be paid to experimentally demonstrating the impacts of invasive species.

Carlton, J. T., J. K. Thompson, et al. (1990). "Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam Potamocorbula amurensis .1. Introduction and dispersal." Marine Ecology Progress Series 66(1-2): 81-94.
The euryhaline bivalve mollusc Potamocorbula amurensis (family Corbulidae), a native of
China, Japan, and Korea, has recently appeared and become very abundant in San Francisco Bay. This
clam appears to have been introduced as veliger larvae in the seawater ballast of cargo vessels. It was
first collected in northern San Francisco Bay in late 1986. P, amurensis then spread throughout the
estuary within 2 yr and reached densities at some sites exceeding 10 000 m-' It lives primarily in the
subtidal on all substrates (mud, sand, peat, and clay) and is found in the full

range of bay salinities (< 1
to 33%). Its explosive increase in abundance and spread may result in major alterations of the San
Francisco Bay estuary ecosystem. These could include changes in (1) trophic dynamics (through
competition with other suspension-feeding and deposit-feeding infauna; changes in benthic community
energy flow; availability of a new and abundant prey item for birds, fish, and crabs; and reduction - as a
result of its filter feeding - of phytoplankton standmg stock) and (2) benthic dynamics (through
inhibition and/or enhancement of infauna due to substrate destabilization; alteration of suspended
sediment load of near-bottom water; and change of sediment surface redox balance). The early
detection of the appearance and spread of P. amurensis in San Francisco Bay makes this one of the best
documented invasions of any estuary in the world.

Caro, T., J. Darwin, T. Forrester, C. LeDoux-Bloom, and C. Wells (2012). "Conservation in the Anthropocene." Conservation Biology 26(1): 4.

It has become commonplace to remark that humans are now the dominant environmental force on the Earth.

The indications are strong and diverse.

Although we agree that humans are a dominant species and have affected natural systems at a global scale,
we suggest that humans may have less influence at smaller extents of specific regions and even ecosystems.
We fear that the concept of pervasive human-caused change may cultivate hopelessness in those dedicated
to conservation and may even be an impetus for accelerated changes in land use motivated by profit.

We recognize that humans have had at least marginal influence on most if not all of the world’s biomes, but
there are several reasons to doubt that humans have altered everything (a phrase that is generously interpreted
as including nutrient flows and species composition and interactions).

While accepting humans’ enormous effect on the planet, we see a crucial need to identify remaining intact
ecosystems at local extents, to protect them, and to remind the public of them. We acknowledge that this is
the goal of many conservation organizations, but we are concerned that the increasing adoption of the concept
of the Anthropocene will undermine both conservation and restoration objectives.

Cashman, J. R., D.A. Maltby, R.S. Nishioka, H.A. Bern, S.J. Gee, and B.D. Hammock (1992). "Chemical contamination and the annual summer die-off of striped bass (Morone saxatilis) in the Sacramento-San Joaquin Delta." Chemical Research in Toxicology 5(1): 100-105.

In 1987, striped bass (Morone saxatilis) that were nearly dead (moribund) were captured by hand net, and apparently healthy striped bass were caught by hook and line from adjacent waters in the Sacramento-San Joaquin Delta or, alternatively, caught by hook and line from the Pacific Ocean. The livers of these three groups of striped bass were examined for chemical contamination by gas chromatography, by gas chromatography-mass spectrometry, and by immunoassay. Moribund striped bass livers were greatly contaminated by chemicals compared to healthy fish caught in the Delta and the Pacific Ocean. The types of contaminant encountered suggested that industrial, agricultural, and urban pollutants were present in the livers of

moribund fish. Although the variability in the amount of hepatic contaminants observed among the groups of fish does not provide direct proof of causation, the large amount of pollutants suggests that chemical contamination (possibly acting as multiple stressors) contributes to the hepatotoxic condition of the moribund striped bass and may lead to an explanation of the die-off in the Sacramento-San Joaquin Delta region.

Caskey, P. S. (1976). Spatial and temporal aspects of the zooplankton distribution in San Francisco Bay. Biology. Hayward, California State University at Hayward: 89.

Cassell, J., S. Murdock, and C. Patterson (2010). Uncertain waters: Navigating California’s water priorities with communities. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Water supply and management is a key issue for the Bay-Delta and the world, which will grown in importance in coming years . Despite it’s importance, citizens are often uninformed about key water management issues in their communities. Public conversations, where knowledge can be shared and discussed are urgent and necessary in light of issues such as the the pending bond initiative on the November 2010 ballot in California. This project will highlight a tool to improve citizen "literacy" with respect to water issues that can be utilized to create a more informed electorate. This project utilizes the National Issues Forum (NIF) format and a new NIF forum discussion guide (developed with support from the California Center for the Book and the Water Education Foundation) to provide a template for community conversations about water in the Bay-Delta region. The NIF format provides the opportunity for mediated discussions to occur with small groups of citizens, where citizens can learn from each other and develop informed positions about water issues. From May - August we will host 10 to 15 conversations in conjunction with libraries in Delta Counties (Contra Costa, Solano, Sacramento, Yolo, and San Joaquin). We hope to expand this project thoroughout the state. The findings of these conversations will be provided to policy-makers via a written report and a video of discussion highlights. This presentation will provide a preview of our findings and report from this unique project.

Castillo, G., J. Morinaka, J. Lindberg, R. Fujimura, B. Baskerville-Bridges, J. Hobbs, G. Tigan, and L. Ellison (2010). Evaluation of fish facility efficiency and pre-screen loss for delta smelt in the State Water Project. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The long-term decline of fish catches in the upper San Francisco Estuary has been linked to water conveyance and export operations by the State Water Project (SWP) and Central Valley Project (CVP). The uncertain connection between reported delta smelt salvage and underlying entrainment losses has precluded basic understanding on the magnitude and variability of entrainment losses and their population level effects. We conducted the first mark-recapture evaluation of the relation between delta smelt salvage at the Skinner Fish Facility (SFF) and underlying entrainment losses at the SWP in the south Delta. We conducted mark-recapture experiments using cultured delta smelt in February and March 2009 (adults) and June 2009 (juveniles) to estimate: 1) the percent of fish recaptured at SFF of the total released at the entrance of SFF (fish facility efficiency); 2) the percent of fish recaptured at SFF of the total released at the entry point of Clifton Court Forebay (CCF), a reservoir for SWP exports (percent recovery); 3) the fish losses in CCF (pre-screen loss). All fish released (n) were calcein-marked; adults were additionally photonically- and strontium-marked. Fish facility efficiency declined in successive releases: February (52.0%, n = 400), March (44.0%, n = 200) and June (24%, n = 800). The percent recovery of fish released in CCF declined greatly over time: February (2.98%, n = 5,707); March (0.42%, n = 2,849) and June (0.03%, n = 14,413). Pre-screen losses increased in consecutive releases: February (94.2%); March (99.0%) and June (99.9%). We concluded that: 1) delta smelt can be readily mass-marked to quantify entrainment losses; 2) pre-screen loss was overwhelmingly the largest source of mortality for delta smelt; 3) entrainment monitoring in CCF seems essential to quantify the connection between salvage statistics, residence time in CCF and the magnitude and variability of direct delta smelt losses.

Castillo, G. (2010). Initial evaluation of entrainment losses for delta smelt in the State Water Project. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Castleberry, D. T., J. J. Cech, Jr., et al. (1993). "Growth, condition, and physiological performance of juvenile salmonids from the lower American River: February through July, 1992."

Casulli, V. and R. T. Cheng (1992). "Semi-implicit finite difference methods for three-dimensional shallow water flow." International Journal for Numerical Methods in Fluids 15: 629-648.
A semi-implicit finite difference method for the numerical solution of three-dimensional shallow water flows is presented and discussed. The governing equations are the primitive three-dimensional turbulent mean flow equations where the pressure distribution in the vertical has been assumed to be hydrostatic. In the method of solution a minimal degree of implicitness has been adopted in such a fashion that the resulting algorithm is stable and gives a maximal computational efficiency at a minimal computational cost. At each time step the numerical method requires the solution of one large linear system which can be formally decomposed into a set of small three-diagonal systems coupled with one five-diagonal system. All these linear systems are symmetric and positive definite. Thus the existence and uniqueness of the numerical solution are assured. When only one vertical layer is specified, this method reduces as a special case to a semi-implicit scheme for solving the corresponding two-dimensional shallow water equations. The resulting two- and three-dimensional algorithm has been shown to be fast, accurate and mass-conservative and can also be applied to simulate flooding and drying of tidal mud-flats in conjunction with three-dimensional flows. Furthermore, the resulting algorithm is fully vectorizable for an efficient implementation on vector computers.

Cavallo, B., P. Bergman, and K. Jones (2010). Application of a winter run chinook life-cycle model to evaluate conservation measures and proposed water project operations. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Following the listing of a majority of salmon and steelhead populations on the U.S. Pacific Coast under the Endangered Species Act (ESA), debate began over the type and magnitude of actions needed to recover listed populations. The CALFED Science Independent Review of the analytical framework for assessing water project operations recommended the development of an integrative life-cycle, spatially explicit population model. We developed such a life-cycle model (operating on a daily time step) and used it to evaluate the influence of alternative water project operations (flows, temperatures, exports, floodplain inundation, Delta routing) and the effectiveness of conservation measures (habitat enhancements, predator reductions, harvest management, non-physical barriers) on winter run Chinook abundance and productivity. Model functions and parameters were derived from existing monitoring studies, especially mark-recapture data from acoustic and coded wire tag studies. Results indicate that water temperatures for egg incubation, predation mortality in the Sacramento River and Delta, and ocean harvest are major drivers of winter run Chinook abundance trends. Increased Yolo Bypass flooding and reduced South Delta exports yielded smaller benefits. Our life-cycle modeling proved to be a useful approach for distinguishing potential benefits of various recovery actions, framing expectations for population growth, and identifying critical data needs to support future management.

Cayan, D. R., and D.H. Peterson (1989). The influence of North Pacific atmospheric circulation on streamflow in the west. Aspects of climate variability in the pacific and western Americas. D. H. Peterson. Washington, D.C., American Geophysical Union. Geophysical Monograph 55: 375-397.
The annual cycle and nonseasonal variability of streamflow over western North America and Hawaii is studied in terms of atmospheric forcing elements. This study uses several decades of monthly average streamflow beginning as early as the late 1800’s over a network of 38 stations. In addition to a strong annual cycle in

mean streamflow and its variance at most of the stations, there is also a distinct annual cycle in the autocorrelation of anomalies that is related to the interplay between the annual cycles of temperature and precipitation. Of particular importance to these lag effects is the well-known role of water stored as snow pack, which controls the delay between peak precipitation and peak flow and also introduces persistence into the nonseasonal streamflow anomalies, with time scales from 1 month to over 1 year. The degree to which streamflow is related to winter atmospheric circulation over the North Pacific and western North America is tested using correlations with time averaged, gridded sea level pressure (SLP), which begins in 1899. Streamflow fluctuations show significant large-scale correlations for the winter (December through February mean SLP anomaly patterns over the North Pacific with maximum correlations ranging from 0.3 to about 0.6. For streams along the west coast corridor the circulation pattern associated with positive streamflow anomalies is low pressure centered off the coast to the west or northwest, indicative of increased winter storms and an anomalous westerly-to-southwesterly wind component. For streams in the interior positive streamflow anomalies are associated with a positive SLP anomaly stationed remotely over the central North Pacific, and with negative but generally weaker SLP anomalies locally. One important influence on streamflow variability is the strength of the Aleutian Low in winter. This is represented by the familiar Pacific-North America (PNA) index and also by an index defined herein the “CNP” (Central North Pacific). This index, beginning in 1899, is taken to be the average of the SLP anomaly south of the Aleutians and the western Gulf of Alaska. Correlations between PNA or CNP and regional anomalies reflect streamflow the alternations in strength and position of the mean North Pacific storm track entering North America as well as shifts in the trade winds over the subtropical North Pacific. Regions whose streamflow is best tuned to the PNA or CNP include coastal Alaska, the northwestern United States, and Hawaii; the latter two regions have the opposite sign anomaly as the former. The pattern of streamflow variations associated with El Nino issimilar, but the El Nino signal also includes a tendency for greater than normal streamflow in the southwestern United States. These indices are significantly correlated with streamflow at one to two seasons in advance of the December-August period, which may allow modestly skillful forecasts. It is important to note that streamflow variability in some areas, such as British Columbia and California, does not respond consistently to these broad scale Pacific atmospheric circulation indices, but is related to regional atmospheric anomaly features over the eastern North Pacific. Spatially, streamflow anomalies are fairly well correlated over scales of several hundred kilometers. Inspection of the spatial anomalies of streamflow in this study suggest an asymmetry in the spatial pattern of positive versus negative streamflow anomalies in the western United States: dry patterns have tended to be larger and more spatially coherent than wet patterns.

Cayan, D. R., P. D. Bromirski, et al. (2008). "Climate change projections of sea level extremes along the California coast." Climatic Change 87: S57-S73.

California's coastal observations and global model projections indicate that California's open coast and estuaries will experience rising sea levels over the next century. During the last several decades, the upward historical trends, quantified from a small set of California tide gages, have been approximately 20 cm/century, quite similar to that estimated for global mean sea level. In the next several decades, warming produced by climate model simulations indicates that sea level rise (SLR) could substantially exceed the rate experienced during modem human development along the California coast and estuaries. A range of future SLR is estimated from a set of climate simulations governed by lower (B1), middle-upper (A2), and higher (A1fi) GHG emission scenarios. Projecting SLR from the ocean warming in GCMs, observational evidence of SLR, and separate calculations using a simple climate model yields a range of potential sea level increases, from 11 to 72 cm, by the 2070-2099 period. The combination of predicted astronomical tides with projected weather forcing, El Nino related variability, and secular SLR, gives a series of hourly sea level projections for 2005-2100. Gradual sea level rise progressively worsens the impacts of high tides, surge and waves resulting from storms, and also freshwater floods from Sierra and coastal mountain catchments. The occurrence of extreme sea levels is pronounced when these factors coincide. The frequency and magnitude of extreme events, relative to current levels, follows a sharply escalating pattern as the magnitude of future sea level rise increases.

Cayan, D. R. and D. H. Peterson (1993). "Spring climate and salinity in the San Francisco Bay Estuary." Water Resources Research 29: 293-303.

Salinity in the San Francisco Bay Estuary almost always experiences its yearly maximum during late summer, but climate variability produces marked interannual variations. The atmospheric circulation pattern impacts the estuary primarily through variations of runoff from rainfall and snowmelt from the Sierra Nevada and, secondarily, through variations in the near-surface salinity in the coastal ocean. While winter precipitation is the primary influence upon salinity in the estuary, spring climate variations also contribute importantly to salinity fluctuations. Spring atmospheric circulation influences both the magnitude and the timing of freshwater flows, through anomalies of precipitation and temperature. To help discriminate between the effects of these two influences, the record is divided into subsets according to whether spring conditions in the region are cool and wet, warm and wet, cool and dry, or warm and dry. Warm springs promote early snowmelt-driven flows, and cool springs result in delayed flows. In addition to effects of winter and spring climate variability operating on the watershed, there are more subtle effects that are transmitted into the estuary from the coastal ocean. These influences are most pronounced in cool and dry springs with high surface salinity (SS) in the coastal ocean versus cool and wet springs with low SS in the coastal ocean. A transect of SS records at stations from the mouth to the head of the bay suggests that the coastal ocean anomaly signal is attenuated from the mouth to the interior of the estuary. In contrast, a delayed, postsummer signal caused by winter and spring runoff variations from the upstream watershed are most pronounced at the head of the estuary and attenuate toward the mouth.

Cayan, D. R., K. T. Redmind, et al. (1999). "ENSO and hydrologic extremes in the western United States." Journal of Climate 12: 2881-2893.

Frequency distributions of daily precipitation in winter and daily stream flow from late winter to early summer, at several hundred sites in the western United States, exhibit strong and systematic responses to the two phases of ENSO. Most of the stream flows considered are driven by snowmelt. The Southern Oscillation index (SOI) is used as the ENSO phase indicator. Both modest (median) and larger (90th percentile) events were considered. In years with negative SOI values (El Nino), days with high daily precipitation and stream flow are more frequent than average over the Southwest and less frequent over the Northwest. During years with positive SOI values (La Nina), a nearly opposite pattern is seen. A more pronounced increase is seen in the number of days exceeding climatological 90th percentile values than in the number exceeding climatological 50th percentile values, for both precipitation and stream flow. Stream flow responses to ENSO extremes are accentuated over precipitation responses. Evidence suggests that the mechanism for this amplification involves ENSO-phase differences in the persistence and duration of wet episodes, affecting the efficiency of the process by which precipitation is converted to runoff. The SOI leads the precipitation events by several months, and hydrologic lags (mostly through snowmelt) delay the stream flow response by several more months. The combined 6-12-month predictive aspect of this relationship should be of significant benefit in responding to flood (or drought) risk and in improving overall water management in the western states.

Cech, J. J., Jr. (1981). "Comparative growth and respiration of juvenile white sturgeon and striped bass." Estuaries 4(3): 254.

Growth rates (ad lib. Artemia diet) and respiratory metabolic (oxygen consumption) rates were measured in juvenile (1 to 6 g wet mass) striped bass (Morone saxatilis) and white sturgeon (Acipenser transmontanus). Growth of sturgeon was significantly greater at 20 degree C compared with 15 degree C, but there was no difference between 20 and 25 degree C. Striped bass growth increased with each increment of temperature elevation. Environmental hypoxia (90 torr P sub(O2)) reduced growth of sturgeon within each temperature regime, whereas striped bass growth was reduced by hypoxia only at the upper two temperatures. Increased temperatures generally increased respiratory metabolism. Hypoxia depressed respiration at all temperatures in striped bass, but did not affect sturgeon respiration.

Cech, J. J., Jr., S.J. Mitchell, D.T. Castleberry, and M. McEnroe (1990). "Distribution of California stream fishes: influence of environmental temperature and hypoxia." Environmental Biology of Fishes 29(2): 95-105.
Metabolic rates of seven fish species were used to assess the importance of temperature and dissolved oxygen as factors affecting longitudinal distributions of stream fish within California drainages. Metabolic rates of all species generally increased at higher acclimation temperatures and with abrupt temperature increases. In response to low dissolved oxygen, four species showed no change in metabolic rates up to a threshold temperature where hypoxia-induced metabolic depression was apparent. These threshold temperatures were near the lethal temperatures for each species. In contrast, two species showed metabolic depressions at every temperature, whereas one showed no depression at any temperature. In general, species occupying similar longitudinal positions in California streams behaved similarly in their metabolic responses. For most species, there was good correspondence between metabolic response and relevant field observations of occurrence. In cases where our analysis predicted species presence in waters where they did not exist, other abiotic factors, such as flow rate, or biotic factors, such as predation or competition, must be considered.

Cech, J. J., Jr., S. J. Mitchell, et al. (1984). "Comparative growth of juvenile white sturgeon and striped bass: Effects of temperature and hypoxia." Estuaries 7(1): 12-18.
The influences of temperature and environmental hypoxia on the growth rates of two California anadromous fishes, white sturgeon (Acipenser transmontanus) and striped bass (Morone saxatilis) were examined. Fish (0.5-0.6 g initial weight) were fed ad libitum rations of Artemia in flow-through aquaria regulated for temperature (15, 20, and 25 degree C) and oxygen tension (130 and 90 torr P sub(O2)). Growth of sturgeon was significantly greater at 20 degree C compared with 15 degree C. Striped bass growth increased with each 5 degree increment of temperature elevation to 3.2% body weight per d at 25 degree C, the fastest growth rate measured. The temperature of maximum growth reflected the temperature of the native estuarine rearing area. Environmental hypoxia (90 torr P sub(O2)) reduced growth of sturgeon within each temperature level, where as striped bass growth was reduced by hypoxia only at the upper two temperatures.

Cech, J. J., Jr., C. Swanson, et al. (1999). Swimming behavior of splittail in multi-vector flow regimes: Applications for fish screens. Fish Performance Studies. D. MacKinlay, K. Howard and J. Cech, Jr.: 111-114.
The splittail, Pogonichthys macrolepidotus (Ayres), used to be one of the most abundant estuarine species in the Sacromento-San Joaquin estuary to which it is endemic and supported a small, but enthusiastic, hook-and-line fishery. It is considered primitive compared to other endemic cyprinid fishes of the California central valley because of its two rows of pharyngeal teeth in contrast to the more advanced characteristic of one row. It was once widely distributed throughout the California central valley but disappeared from much of its native range because of loss or alteration of lowland habitats following dam construction, water diversion, and agricultural development, and is now restricted to the estuary. Juvenile splittail are now subject to entrainment and impingement at >2000 water diversions located within their current habitat. Three alternatives currently being considered to improve estuarine habitats include construction of large fish screens to better separate fish from water diverted for municipal and industrial uses. Water in front of these large screenss would have complex flows from both approach flows and sweeping flows. The objective of this study was to examine the swimming performance and behavior of splittail exposed to complex flow regimes in a circular flume, equipped with a fish screen, termed a fish treadmill.

Chadwick, H. K. (1962). "Catch records from the striped bass sport fishery in California." California Fish and Game 48: 153-177.

Chadwick, H. K. (1963). "An evaluation of five tag types used in a striped bass mortality rate and migration study." California Fish and Game 49: 64-83.

Chadwick, H. K. (1964). "Annual abundance of young striped bass, Roccus saxatilis, in the Sacramento-San Joaquin Delta, California." California Fish and Game 50: 69-99.

Chadwick, H. K. (1966). "Variation in the growth of young striped bass (Roccus saxatilis), in the Sacramento-San Joaquin Delta, California."

Chadwick, H. K. (1967). "Recent migrations of the Sacramento-San Joaquin River striped bass population." Transactions of the American Fisheries Association 96: 327-342.

Migration patterns of striped bass (Roccus saxatilis) in the Sacramento-San Joaquin River system, California, are defined by tag returns from 18,300 tagged fish and angler catches from 1958 through 1964. Larger adults migrated farther downstream than smaller ones, and most 3- and 4-year-old immature fish remain in the Bay Area during the spawning period. Fish tagged in the western and eastern Delta during the spring, in the western Delta during the fall, in the upper Sacramento River during the spring, and in San Pablo Bay during the fall all had similar migration patterns. The only general difference was each group had a distinctive migration to the Delta. Migrations into San Francisco Bay and the Pacific Ocean were much greater in the late 1950's and early 1960's than in the early 1950's. Data on changes in the striped bass population and environment were insufficient to explain migration changes. Earlier conclusions regarding factors controlling seaward migration did not adequately explain migration variations between 1958 and 1964.

Chadwick, H. K. (1968). "Mortality rates in the California striped bass population." California Fish and Game 54: 228-246.

Chadwick, H. K. (1969). "An evaluation of striped bass angling regulations based on an equilibrium yield model." California Fish and Game 55: 12-19.

Chadwick, H. K. (1977). Effects of water development on striped bass. Proceedings of the Second Marine Recreational Fisheries Symposium. Washington, D.C, Sport Fishing Institute: 123-130.

Chadwick, H. K., D. E. Stevens, et al. (1977). Some factors regulating the striped bass population in the Sacramento-San Joaquin Estuary, California. Proceedings of the Conference on Assessing the Effects of Power-Plant-Induced Mortality on Fish Populations, Gatlinburg, Tennessee, May 3-6, 1977. W. V. Winkle. New York, Pergamon Press: 18-35.

The abundance of young and adult striped bass (Morone saxatilis) in the Sacramento-San Joaquin Estuary is related to the magnitude of water diversion and of water flow in the estuary. Principal variations in survival occur during the first two months of life. Density-independent mortality caused by the loss of young bass in water diversions is a major factor regulating population size. Population size is also directly related to flow rates, which serve to control the transport of young bass to suitable nursery areas, which in turn influence survival through factors such as food availability.

Chan, A. (2010). Water Levels in San Francisco Bay, Water Years 2008 and 2009. IEP Newsletter. 23: 2.

Chang, A., S. Attoe, P. Malm, J. Fisher, and S. Morgan (2010). Going with the flow or staying close to home? Population connectivity, freshwater flow, and native oyster restoration in San Francisco Bay. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

A key missing piece of information for managers working to restore populations of the native oyster, Ostrea conchaphila, in San Francisco Bay is a clear picture of the links between populations in different parts of the Bay. Knowledge of population connectivity also will greatly improve our understanding of the causes and consequences of fluctuations in abundance and geographic distribution, as well as responses to floods, droughts, and many other disturbances. Do populations in some areas act as sources of larvae that maintain populations in other parts of the Bay? Are some apparently thriving oyster populations only able to keep up appearances due to constant inflow of larvae from source populations

elsewhere? Do connectivity patterns change with altered freshwater outflow levels entering the Bay? We investigated oyster population dynamics and larval dispersal patterns in San Francisco Bay using a combination of population surveys, recruitment monitoring, and trace elemental fingerprinting methods. We examined oyster populations during the low flow season at the end of a three-year drought (Fall 2009) and during higher flow conditions (Spring 2010). In the fall of 2009, oyster abundance and size distributions differed significantly along the salinity gradient from upstream sites toward the mouth of the Golden Gate, with a maximum density of over 300 oysters / m2 occurring in brackish waters near China Camp State Park. Significant regional variation in temperature and salinity conditions appear to be correlated with differences in timing of spawning and settlement throughout the year. Juvenile recruitment varied significantly around the Bay, with greatest settlement in moderately-to-high salinity areas, especially during warmer periods. Oyster larvae from different sites around the Bay contained sufficiently distinct trace elemental fingerprints to be discriminated from each other at fairly small spatial scales. Natal origins of collected juveniles are currently being investigated and will be presented.

Chapman, E. D., Hearn, A.R., Michel, C.J., Ammann, A.J., Lindley, S.T., Thomas, M.J. Sandstrom, P.T., Singer, G.P., Peterson, M.L., MacFarlane, R.B., and Klimley, A.P. (2012). "Diel movements of out-migrating Chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (Oncorhynchus mykiss) smolts in the Sacramento/San Joaquin watershed. ." Environmental Biology of Fishes DOI: 10.1007/s10641-012-0001-x.
We used ultrasonic telemetry to describe the movement patterns of late-fall run Chinook salmon (Oncorhynchus tshawytscha) and steelhead trout (O. mykiss) smolts during their entire emigration down California’s Sacramento River, through the San Francisco Bay Estuary and into the Pacific Ocean. Yearling hatchery smolts were tagged via intracoelomic surgical implantation with coded ultrasonic tags. They were then released at four upriver locations in the Sacramento River during the winters of 2007 through 2010. Late-fall run Chinook salmon smolts exhibited a nocturnal pattern of migration after release in the upper river. This is likely because individuals remain within a confined area during the day, while they become active at night and migrate downstream. The ratio between night and day detections of Chinook salmon smolts decreased with distance traveled downriver. There was a significant preference for nocturnal migration in every reach of the river except the Estuary. In contrast, steelhead smolts, which reside upriver longer following release, exhibited a less pronounced diel pattern during their entire migration. In the middle river, Delta, and Estuary, steelhead exhibited a significant preference for daytime travel. In the ocean Chinook salmon preferred to travel at night, yet steelhead were detected on the monitors equally during the night and day. These data show that closely related Oncorhynchus species, with the same ontogenetic pattern of out-migrating as yearlings, vary in migration tactic.

Chapman, F. A., J. P. Van Eenennaam, et al. (1996). "The reproductive condition of white sturgeon, Acipenser transmontanus, in San Francisco Bay, California." Fishery Bulletin 94(4): 628-634.
White sturgeon, Acipenser transmontanus, adults (n=855) were collected on their feeding grounds in San Francisco Bay, California, and their sex and stage of sexual maturity were evaluated histologically. They did not exhibit external sexual dimorphism, and the overall sex ratio did not differ from 1:1. Average fork length was 139 cm plus or minus 1.1 cm (mean plus or minus standard error of the mean); females were longer (145 cm plus or minus 1.2 cm, n=443) than males (133 cm plus or

minus 1.0 cm, n=412). In smaller size classes (less than or equal to 115 cm), males were significantly (P<0.05) more numerous than females. The proportion of females, however, was significantly higher among larger fish (>155 cm). The sample of females consisted of 70% fish with "immature" (previtellogenic) ovaries, 12% with "maturing" (vitellogenic) ovaries, and 18% with "ripe" (large, pigmented eggs) ovaries. In contrast, most males were either "maturing" (meiosis, 56%) or "ripe" (spermatozoa, 39%). Ripe females represented only 9% of all fish sampled. Egg production by females, estimated by hatchery spawning, averaged 5,648 eggs/kg of body weight. The length at which white sturgeon in San Francisco Bay attain sexual maturity was estimated to be 95-135 cm in females and 75-105 cm in males. The duration of one ovarian cycle in iteroparous females was estimated to be longer than one year, with an apparent 2- to 4-year interval between spawning periods; the reproductive cycle of males was estimated to be 1-2 years. The low reproductive potential of white sturgeon in San Francisco Bay should be considered in fishery management of the species.

Chapman, P. M., R. Dexter, et al. (1987). "Synoptic measures of sediment contamination, toxicity and infaunal community composition (the Sediment Quality Triad) in San Francisco Bay." Marine Ecology Progress Series 37: 75-96.
The utility of the Sediment Quality Triad was assessed in determining pollution-induced degradation. This approach consists of synoptic measurements of sediment contamination by chemical analyses, sediment toxicity through bioassays, and benthic infaunal community structure through taxonomic analyses of macroinfauna. Each component of the Triad complements the other 2 and together all 3 component provide an objective assessment of pollution-induced degradation. The underlying hypothesis is that no component can be used to predict measurements of the other 2 components. Sediment samples were collected at 3 stations at each of 3 sites in San Francisco Bay, USA, and subjected to 4 separate, replicated sediment bioassays, comprehensive sediment chemistry analyses (no replication), and replicated benthic infaunal analyses.

Chappell, E. (2004). Chinook salmon catch and escapement. IEP Newsletter. 2: 5.

Chauvaud, L., J. K. Thompson, et al. (2003). "Clams as CO2 generators: The Potamocorbula amurensis example in San Francisco Bay." Limnology and Oceanography 48(6): 2086-2092.
Respiration and calcium carbonate production by the invasive Asian clam, Potamocorbula amurensis, were calculated to assess their importance as CO2 sources in northern San Francisco Bay. Production, calculated using monthly population density and size structure measured at three sites over 7 yr and a shell length/CaCO3 conversion factor, averaged 221 (+/-184) g CaCO3 m(-2) yr(-1). Net calcium carbonate production by this exotic bivalve releases CO2 at a mean rate of 18 (+/-17) g C m(-2) yr(-1). Respiration by P. amurensis, estimated from secondary production, releases additional CO2 at a mean rate of 37 (+/-34) g C m(-2) yr(-1). Therefore, total net CO2 production by P. amurensis averages 55 (+/-51) g C m(-2) yr(-1) in an estuarine domain where net primary production consumes only 20 g inorganic C m(-2) yr(-1). CO2 production by P. amurensis in northern San Francisco Bay is an underestimate of the total CO2 supply from the calcified zoobenthic communities of San Francisco Bay, and results from other studies have suggested that this rate is not unusual for temperate estuaries. Global extrapolation yields a gross CO2 production rate in the world's estuaries of 1 X 10(14) g C yr(-1), which suggests that calcified benthic organisms in estuaries generate CO2 equal in magnitude to the CO2 emissions from the world's lakes or from planetary volcanism (the net source is determined by the highly variable rate of CO2 consumption by carbonate dissolution). This biogenic CO2 source is increasing because of the continuing global translocation of mollusks and their successful colonization of new habitats.

Chen, C. W., D. Leva, et al. (1996). "Modeling the fate of copper discharged to San Francisco Bay." Journal of Environmental Engineering 122(10): 924-934.
An existing two-dimensional estuary model was modified to incorporate processes important to the transport and fate of copper in San Francisco Bay. These processes include advection, dispersion, partitioning with suspended particles,

settling, and resuspension of adsorbed copper. A systematic calibration of these processes was made. The simulated advection was first shown to match tidal stages, time lag of slack waters, and currents. The model's dispersion was then calibrated by matching observed total dissolved solids. Finally, the model was calibrated to match total suspended solids, total copper, dissolved copper, and sediment copper. The model simulated the recently observed copper concentration in the bay under current point and nonpoint source loadings. The model predicted that a reduction of copper load in winter storm-water runoff would lower copper concentration in the summer.

Chen, X., and J. Stillman (2010). Is there a synergistic effect of thermal and osmotic stress on metabolic performance in freshwater zooplankton? 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The Sacramento -San Joaquin Delta is a highly altered estuarine ecosystem. People regulate the storage and diversion of freshwater from Sacramento River and San Joaquin River to serve human consumption and agriculture. Reduced freshwater flow during dry seasons, warm temperatures and increasing tidal inundation result in seasonally obvious variations of temperature and salinity. To investigate the synergistic effect of thermal and osmotic stress on metabolic performance in freshwater zooplankton, Daphnia pulex were exposed to 9 different combinations of daily fluctuations in temperature (15, 15-25, 15-30°C) and salinity (0, 0-2, 0-5ppt). Metabolic rates and growth rates of 5 replicate isofemale lines of Daphnia pulex cultured in each condition were measured and recorded at the 1st and 5th generations. Microplate optode respirometry was performed at 15°C and 0ppt. Daphnia exposed to the treatments of 15-30°C 0ppt, and 15-30°C 0-5ppt showed the lowest metabolic rates at both 1st and 5th generations. However, no obvious lower metabolic rates were observed in other treatments, indicating that high temperature is the dominant factor for the synergistic effect of temperature and salinity on metabolism. Daphnia developed from newborn to adult in 2-3 fewer days in the 15-25°C treatments than at other temperatures. Exposure to lower temperature may slow growth due to Q10 effects, whereas exposure to higher temperatures may slow growth due to energetic tradeoffs with stress responses.

Cheng, R. and L. Smith (1985). Tidal hydraulics of San Francisco Bay and Estuary. Symposium II, Selenium and Agricultural Drainage;, Berkeley, CA.

Cheng, R. T. and V. Casulli (1992). Dispersion in tidally averaged transport equation. Dynamics and Exchanges in Estuaries and the Coastal Zone. D. Prandle. Washington, AGU. 38, Coastal and Estuarine Studies: 409-428.

Cheng, R. T. and V. Casulli (1996). Modeling the periodic stratification and gravitational circulation in San Francisco Bay. Proceedings of the Fourth International Conference on Estuarine and Coastal Modeling. M. L. Spaulding and R. T. Cheng. San Diego, ASCE: 240-254.

Cheng, R. T., V. Casulli, et al. (1993). "Tidal, residual, intertidal mudflat (TRIM) model and its applications to San-Francisco Bay, California." Estuarine, Coastal, and Shelf Science 36(3): 235-280.

A numerical model using a semi-implicit finite-difference method for solving the two-dimensional shallow-water equations is presented. The gradient of the water surface elevation in the momentum equations and the velocity divergence in the continuity equation are finite-differenced implicitly, the remaining terms are finite-difference explicitly. The convective terms are treated using an Eulerian–Lagrangian method. The combination of the semi-implicit finite-difference solution for the gravity wave propagation, and the Eulerian–Lagrangian treatment of the convective terms renders the numerical model unconditionally stable. When the baroclinic forcing is included, a salt transport equation is coupled to the momentum equations, and the numerical method is subject to a weak stability condition. The method of solution and the properties of the numerical model are given. This numerical model is particularly suitable for applications to coastal plain estuaries and tidal embayments in which tidal currents are dominant, and tidally generated residual currents are important. The model is applied to San Francisco Bay,

California where extensive historical tides and current-meter data are available.

Cheng, R. T. and J. W. Gartner (1984). Tides, tidal, and residual currents in San Francisco Bay, California --Results of measurements, 1979-1980: 319 p.

Cheng, R. T., J. W. Gartner, et al. (1998). Flow and suspended particulate transport in a tidal boundary layer, south San Francisco Bay, California. Physics of Estuaries and Coastal Seas. J. Dronkers and M. Scheffers. Rotterdam, Balkema: 3-12.

Cheng, R. T., J. W. Gartner, et al. (1997). "Bottom boundary layer in south San Francisco Bay, California." Journal of Coastal Research SI25: 49-62.

Cheng, R. T., C.-H. Ling, et al. (1999). "Estimates of bottom roughness length and bottom shear stress in South San Francisco Bay, California." Journal of Geophysical Research. C. Oceans 104(C3): 7715-7728.
A field investigation of the hydrodynamics and the resuspension and transport of particulate matter in a bottom boundary layer was carried out in South San Francisco Bay (South Bay), California, during March-April 1995. Using broadband acoustic Doppler current profilers, detailed measurements of turbulent mean velocity distribution within 1.5 m above bed have been obtained. A global method of data analysis was used for estimating bottom roughness length z sub(o) and bottom shear stress (or friction velocities u*). Field data have been examined by dividing the time series of velocity profiles into 24-hour periods and independently analyzing the velocity profile time series by flooding and ebbing periods. The global method of solution gives consistent properties of bottom roughness length z sub(o) and bottom shear stress values (or friction velocities u*) in South Bay. Estimated mean values of z sub(o) and u* for flooding and ebbing cycles are different. The differences in mean z sub(o) and u* are shown to be caused by tidal current flood-ebb inequality, rather than the flooding or ebbing of tidal currents. The bed shear stress correlates well with a reference velocity; the slope of the correlation defines a drag coefficient. Forty-three days of field data in South Bay show two regimes of z sub(o) (and drag coefficient) as a function of a reference velocity. When the mean velocity is >25-30 cm s super(-1), the ln z sub(o) (and thus the drag coefficient) is inversely proportional to the reference velocity. The cause for the reduction of roughness length is hypothesized as sediment erosion due to intensifying tidal currents thereby reducing bed roughness. When the mean velocity is <25-30 cm s super(-1), the correlation between z sub(o) and the reference velocity is less clear. A plausible explanation of scattered values of z sub(o) under this condition may be sediment deposition. Measured sediment data were inadequate to support this hypothesis, but the proposed hypothesis warrants further field investigation.

Cheng, R. T., D. McKinnie, et al. (1998). An overview of San Francisco Bay PORTS. Proceedings, Ocean Community Conference. Marine Technology Society. p. 1054-1060, Baltimore, MD.

Cheng, R. T., P. E. Smith, et al. (1993). Recent development in three-dimensional numerical estuarine models. Proceedings, 1993 National Conf. on Hydraulic Engineering, ASCE, July 1993 p. 1982-1987, San Francisco, California.

Cheng, R. T. and R. E. Smith (1998). A nowcast model for tides and tidal currents in San Francisco Bay, California. Proceedings, Ocean Community Conference, Marine Technology Society. p. 537-543, Baltimore, MD.

Cherry, D. E., W.E. Templin, and T.C. Haltom (1993). Industrial water use in California. Effluent Use Management, 29th Annal Conference Abstracts, Tucson, AZ, American Water Resources Association.

Cherry, D. E., J.M. Wright, W.E. Templin, and T.C. Haltom (1993). Water use at golf courses, amusement parks, and ski areas in California. Effluent Use Management, Tucson, AZ, American Water Resources Association.

Chesney, E. J., Jr. (1989). "Estimating food requirements of striped bass larvae,

Morone saxatilis: effects of light, turbidity and turbulence." Marine Ecology Progress Series 53: 191-200.
Laboratory experiments were conducted to study the effects of food concentration, turbulence and turbidity on growth and survival of striped bass larvae Morone saxatilis. Initial experiments indicated that striped bass larvae could forage and grow well (G = 0.143 to 0.179 d-1) at food concentrations ranging from 50 to 250 ind I-1 of the copepod Eurytemora affinis and that growth was similar on Artemia sp. and E. affinis. Subsequent experiments tested effects of turbidity (50, 100, 150 ppm kaolin), reduced light intensity(2000, 1000, 600, 300 lux) and turbulence, separately, and then reduced light intensity (450, 70, 12, 0.4 lux) in combination with turbidity (150ppm kaolin) and turbulence to determine how these variables moderate food requirements of striped bass larvae. Reducing light or adding turbulence reduced growth and forage rates, while adding turbidity in combination with turbulence apparently ameliorated some of the negative effects of the turbulence. Although growth studies indicated an energetic cost of turbulence, additional experiments comparing weight loss and starvation mortality in turbulent versus non-turbulent conditions showed no significant differences. A comparison of individual growth variability (G) in the turbidity (150 ppm) reduced light treatments and the treatment in total darkness without turbidity or turbulence showed that whileaverage growth rates were positive, a portion of the individuals surviving until 25 d after hatch were either not growing or losing weight. Low light level in combination with turbidity and turbulence substantially reduced survival and growth rate, but even at very low light levels (< 1 lux) and darkness, striped bass were able to survive and grow. Results indicate that previous studies of critical food requirements of striped bass larvae may have overestimated necessary prey levels. Although striped bass larvae are well adapted for growth and survival in highly turbulent, turbid environments, encountering poor feeding conditions in the field is likely to greatly reduce their probability of survival to the juvenile stage.

Choe, K.-Y., G. A. Gill, et al. (2004). "Sediment-water exchange of total mercury and monomethyl mercury in the San Francisco Bay-Delta." Limnology and Oceanography 49(5): 1512-1527.
Five field trips were conducted in the San Francisco Bay-Delta between May 2000 and October 2001 to investigate the sediment-water exchange of total mercury (Hg) and monomethyl mercury (MMHg). Solid-phase Hg averaged similar to 1 nmol g super(-1) and did not show any variability with depth or time or among sites. In contrast, solid-phase MMHg showed considerable vertical, temporal, and spatial variability (0.4-66 pmol g super(-1)), with the highest values occurring at a peat-rich environment in May 2001, suggesting that MMHg production was largely controlled by temporal factors and habitat type. In pore water, both Hg and MMHg concentrations were generally elevated near the sediment-water interface during warm months. Sediment-water exchange flux of MMHg, determined with benthic chamber deployments, ranged from -92 to 850 pmol m super(-2) d super(-1), with higher values occurring in May. In most cases, diffusional fluxes of Hg and MMHg, estimated with the use of interfacial concentration gradients, constituted only a minor portion of the measured fluxes, suggesting the importance of advective processes on sediment-water exchange. Surface-water transect and time series studies conducted in Franks Tract support the commonly held belief that wetland and marsh regions are major sources for MMHg within the Delta. The integrated sediment-water fluxes of Hg and MMHg in the study area were estimated to be 130 and 6 mmol d super(-1), respectively, and the benthic input was as important a source of Hg and MMHg as the riverine input within the Delta during low-flow months.

Choi, K. H., W. Kimmerer, et al. (2005). "Post-exchange zooplankton in ballast water of ships entering the San Francisco Estuary." Journal of Plankton Research 27(7): 707-714.
The San Francisco Estuary in California (CA), USA, has been heavily altered by invasions of nonnative zooplankton and benthic organisms, presumably by the discharge of ships' ballast water. Since 2000, ships entering CA have been required to exchange ballast water with oceanic water during the voyage to decrease the number of organisms discharged into the Estuary that had previously been taken aboard at foreign ports. We examined abundance of zooplankton in ballast water of 18

container ships and 48 bulk carriers. Asia dominated the sources of ballast water, which contained multiple nonnative zooplankton including species that have invaded and since become common residents in the Estuary. The abundance of zooplankton was significantly lower in ballast water that had been emptied and refilled with oceanic water than those that had continuously been flushed with oceanic water (about three times the volume of ballast water), suggesting that empty-refill is more effective in removing exotic zooplankton.

Choi, K.-H. and W. J. Kimmerer (2008). "Mate limitation in an estuarine population of copepods." Limnology and Oceanography 43(3): 1656-1664.

We determined the probability of mating as a function of population density in the estuarine copepod Acartia
hudsonica by combining experimental measurements with a simple model. Pairs of unmated copepods were
confined in containers of various volumes to simulate variable population density, and experiments were run for
8, 16, and 24 h. Mating frequencies indicated that males search for females at an effective search volume rate of
0.34 6 0.15 L h21 or 8.2 6 3.5 L d21 and that males become ready to mate only after ,15 h exposure to the
females. We applied these parameters in a simple population model to determine the critical density for zero
population growth. With high egg production, zero mortality, and residence time of 60 d, the critical density for
A. hudsonica was 0.01 m23, at the low end of the range of observed population densities. Critical densities for less
favorable conditions were well within the range of observed population densities, even allowing for the effects of
aggregation. Thus, mate limitation in sexually reproducing organisms, or Allee effects, can cause negative density
dependence in growth rate of these populations at low but realistic population densities. We applied these results
to the introduction of exotic zooplankton via ships' ballast water under various scenarios of initial dilution in
harbors and subsequent conditions for reproduction and survival. Inocula resulting from the discharge of
postexchange ballast water were often high enough to establish new resident populations.

Choi, K.-H. and W. J. Kimmerer (2009). "Mating success and its consequences for population growth of an estuarine copepod." Marine Ecology Progress Series 377: 183-191.

Chotkowski, M. and B. Manly (2006). "Two new methods for Regime Change Analyses." Archiv fur Hydrobiologie 167(1-4): 593-607.

There is currently a good deal of concern about a recently recognized decline in the numbers of several pelagic fish species in the Sacramento-San Joaquin Delta in California, USA. Several research groups are investigating possible reasons for this decline. One part of this study addresses whether the decline is the result of some recent regime change in the ecosystem, and more generally whether one or more regime changes have occurred since regular sampling of fish, zooplankton and mysids shrimps began in 1967. There are mang statistical methods of analysis that have been proposed to detect regime changes. These are reviewed, but it is noted that none of them is immediately suitable for analysing the basic data collected from the Sacramento-San Joaquin Delta, which consists of counts from trawl hauls and other sampling gears used in the field. Two new methods are therefore proposed for this type of data, which is commonly collected. One method searches for timen when the mean level and trend in the abundance of an organism changed, assuming that in the absente of a regime change the abundances will exhibit a linear trend with time. The other method assumes that in the absente of a regime change the abundances will exhibit a polynomial trend in time, and searches for timen when the mean level changed significantly. Both methods rely on bootstrap resampling of the data for assessing the significance of apparent regime changes. Simulation studies to verify

the properties of the proposed analyses are described, and also some examples of the results of the analyses on the Sacramento-San Joaquin data.

Chow, A. T., R. A. Dahlgren, et al. (2007). "Watershed sources of disinfection byproduct precursors in the Sacramento and San Joaquin rivers, California." Environmental Science & Technology 41(22): 7645-7652.
High levels of dissolved organic carbon (DOC) and bromide (Br) in the Sacramento and San Joaquin River waterways are of concern because DOC and Br are organic and inorganic precursors, respectively, of carcinogenic and mutagenic disinfection byproducts (DBPs). The Sacramento and San Joaquin Rivers are the two major rivers supplying water to the San Francisco Bay Delta, but sources and loads of DBP precursors into the Delta are still uncertain. The major objectives of this study were to evaluate both the quantity (DOC and Br fluxes) and the quality (reactivity in forming DBPs) of DBP precursors from the Sacramento and San Joaquin watersheds. Water samples were collected every 2 weeks at up to 35 locations along the Sacramento and San Joaquin Rivers and selected tributaries and analyzed for DOC (4 years), Br (I year), and ultraviolet absorbance at 254 nm (1 year). Selected water samples were also tested for THM formation potential. Estimated fluxes for the Sacramento River were 39 000 +/- 12 000 Mg DOC year(-1) and 59 Mg of Br year(-1) as compared to 9000 +/- 5000 Mg of DOC year(-1) and 1302 Mg of Br year-1 for the San Joaquin River. The THM formation potential was higher in the San Joaquin River (441 +/- 49 mu g L-1) than the Sacramento River (176 +/- 20 mu g L-1) because of higher concentrations of both organic (DOC = 3.62 +/- 0.14 vs 1.92 +/- 0.09 mg L-1) and inorganic DBP (Br = 0.80 +/- 0.07 vs <0.03 +/- 0.01 mg L-1) precursors. The Sacramento River's greater DOC load despite lower DOC concentrations is due to its discharge being about 5 times greater than the San Joaquin River (50 x 10(9) vs 10 x 10(9) L day(-1)). The DOC concentration was significantly correlated with several land-cover types, including agriculture; however, no relationship was found between DOC quality and land-cover at the watershed scale.

Christen, J. (2010). Trend analysis of organic carbon concentrations in the Sacramento-San Joaquin Delta. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
This study was a test for and description of interannual trends in the data collected by the Department of Water Resources for organic carbon concentrations of the major source waters of the Sacramento-San Joaquin Delta and in the Delta waters at the head of the State Water Project. Organic carbon concentrations in the Delta are of interest as a measure of available organic matter in the aquatic food web, as a precursor to regulated disinfection byproducts of the drinking water treatment process, and as a regulated parameter in the drinking water treatment process. The locations examined were the Sacramento River at Hood, the San Joaquin River near Vernalis, and the Banks Pumping Plant in the south Delta. The organic carbon data sets were tested for trend using the non-parametric seasonal Kendall method. The total period of record as well as a subset of the most recent ten water years was examined. Trends in flow were examined as a possible explanatory variable for trends in riverine organic carbon concentrations. Our results indicate that changes in flow are a driver of interannual median dissolved organic carbon (DOC) concentrations in the Sacramento and San Joaquin Rivers and that the interannual relationship between flow and DOC is lagged by one or more years. The finding of a lag in the relationship between flow and a water quality constituent in the Delta waters may serve as an aid to interpretations of other water quality variables or Delta processes.

Cifuentes, L. A., L.E. Schemel, and J.H. Sharp (1990). "Qualitative and numerical analyses of the effects of river inflow variations on mixing diagrams in estuaries." Estuarine, Coastal and Shelf Science 30(4): 411-427.
The effects of river inflow variations on alkalinity/salinity distributions in San Francisco Bay and nitrate/salinity distributions in Delaware Bay are described. One-dimensional, advective-dispersion equations for salinity and the dissolved constituents are solved numerically and are used to simulate mixing in the estuaries. These simulations account for time-varying river inflow, variations in estuarine cross-sectional area, and longitudinally varying dispersion coefficients. The model simulates field observations better than models that use constant

hydrodynamic coefficients and uniform estuarine geometry. Furthermore, field observations and model simulations are consistent with theoretical ‘predictions’ that the curvature of propery-salinity distributions depends on the relation between the estuarine residence time and the period of river concentration variation.

Clark, S. L., S. J. Teh, et al. (2000). "Tissue and cellular alterations in Asian clam (Potamocorbula amurensis) from San Francisco Bay: toxicological indicators of exposure and effect?" Marine Environmental Research 50: 301-305.
The US Geological Survey has reported the presence of a metal contamination gradient in clam tissues, decreased condition indices, and irregular reproductive patterns have been reported in the Asian clam, Potamocorbula amurensis, from San Francisco Bay. If metals are driving the observed patterns in the field, then biomarkers of exposure, and possibly deleterious effect, should show a corresponding gradient. In this study, biomarkers from sub-cellular to tissue levels of biological organization were assessed in P. amurensis collected from the Bay or exposed to cadmium in the laboratory. Cellular and tissue alterations were assessed using histopathology and enzyme histochemistry (EH). Alterations in the ovary, testis, kidney, and gill tissues were most common at the most contaminated station when data were averaged over a 12-month sampling period. EH analysis indicated decreased active transport, energy status, and glucose oxidation in kidney and digestive gland at the most contaminated site which may indicate a decreased potential for growth. Ovarian lesions observed in feral Asian clams were experimentally induced in healthy clams by cadmium exposure in laboratory exposures. Our results suggest a contaminant etiology for tissue alterations.

Cleave, A., and K.E. Boyer (2010). Effects of invasive Limonium ramosissimum on native salt marsh communities in a changing environment. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Limonium ramosissimum, Algerian sea lavender, is an established invader in southern California marshes that is forming monotypic stands in the middle to high elevations of a number of marshes in the San Francisco Bay Estuary. L. ramosissimum’s high salinity tolerance, reproductive rate, and dispersal suggest potential for spread in the Estuary, and understanding of its interactions with native species and effects on ecosystem function is needed. In this project, we are assessing how invasion by L. ramosissimum affects abundance and function of the native amphipod, Traskorchestia traskiana, and how anthropogenic changes may further affect these interactions. At two salt marshes in South San Francisco Bay we established plots of L. ramosissimum, and a native plant, Jaumea carnosa, at two elevations (levels of inundation) as a proxy for sea level rise. To simulate anthropogenic nutrient enrichment, we added nitrogen (N) fertilizer every two weeks during the growing season. Early results indicate that at both marshes, Coyote Point Marina and Sanchez marsh, there was an increase in canopy height in correlation with nutrient addition, but L. ramosissimum canopies were still significantly shorter than J. carnosa. Field observations indicated that the native amphipod habitat preference is for L. ramosissimum. Additional study with stable isotope tracers, evaluation of native amphipod and other insect species use, and decomposition rates will help to further establish ecosystem changes occurring as result of the invasion. This will also help us assess any further anthropogenic induced modifications on ecosystem changes.

Clemento, A., J.C. Garza, and E. Anderson (2010). An integrated genetic stock identification and parentage-based tagging program for Chinook salmon using SNPs. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Populations of West Coast Chinook salmon (Oncorhynchus tshawytscha) have been on the decline over the last decade. Of particular concern is the recent crash of Central Valley (primarily Sacramento River) fall-run Chinook, the main contributor to the commercial and recreational fisheries of California and Oregon. As the situation has become more dire, management agencies are under increasing pressure to tightly monitor and critically evaluate actions meant to preserve the species. This includes not just monitoring and regulating ocean fisheries, but also evaluating the effectiveness of current hatchery practices, the relative fitness of

hatchery produced fish, and the impacts of hatchery fish on wild populations. The aging coded wire tag (CWT) program has been informative towards these goals, however it is expensive and current efforts to mass mark all hatchery fish will further impede the program's effectiveness. In an ideal management world, we would like to pick up a salmon - as a juvenile migrating seaward, in ocean fisheries, or during spawning at hatcheries or instream - and ask the question, "Where did you come from?" The integrated Genetic Stock Identification (GSI) and Parentage-based Tagging (PBT) program described here provides two distinct ways to answer this question by simply collecting a fin clip (non-lethally) and genotyping the individual with a single panel of 96 single nucleotide polymorphism (SNP) markers. GSI provides the origin of an individual by comparing its genotype to baseline samples collected from the primary drainages and rivers to which the fish can be assigned. Alternatively, a PBT program depends on the collection of genotype information from a parental generation, either the broodstock at a hatchery or even wild spawners at a weir. This data is entered into a parent database. When offspring are subsequently sampled, genotyping is followed by high-confidence parentage assignment wherein the inherited genetic tags are used to locate the parents in the database, thereby identifying the stock and cohort of origin. A PBT program also provides some collateral benefits: reconstruction of large pedigrees, mapping of genes for phenotypic traits, precise estimates of variance in family size, and the ability to evaluate different hatchery practices. This talk will focus on the following: 1. SNP discovery at the NOAA SWFSC Santa Cruz Lab 2. marker selection and panel construction 3. status of the GSI SNP baseline for West Coast Chinook salmon 4. GSI results from mixed ocean fisheries: past and present 5. status of broodstock sampling for PBT at California salmon hatcheries 6. results from an applied PBT program at the Feather River Hatchery for spring-run Chinook.

Cloern, J. and A. Alpine (1991). "Potamocorbula amurensis , a recently introduced Asian clam, has had dramatic effects on the phytoplankton biomass and production in northern San Francisco Bay." Journal of Shellfish Research 10(1): 258-259.

Potamocorbula amurensis , a benthic suspension feeding bivalve, accidently introduced in San Francisco Bay in 1986, spread rapidly throughout the estuary with dramatic ecological consequences. Field and laboratory evidence suggest that this species is capable of consuming most of the phytoplankton produced in northern San Francisco Bay. To further define the effects of this invasion a study was initiated in 1988 to examine rates of primary productivity and related parameters to compare with pre-invasion levels. Daily rates of primary productivity were much lower in 1988 compared to rates measured in 1980. These lowered daily productivities led to a dramatic decline in annual production - 1988 production was only 20 g C/m super(2) compared with average annual production of 110 g C/m super(2) during pre-invasion years. It is believed this decline in production is a consequence of the consumption of phytoplankton by P. amurensis). Preliminary measurements of P. amurensis feeding rates and densities in the field are sufficient to account for the reduction in phytoplankton biomass in northern San Francisco Bay during the past 4 years.

Cloern, J., A. Alpine, et al. (1983). "River discharge controls phytoplankton dynamics in the northern San Francisco Bay estuary." Estuarine, Coastal, and Shelf Science 16: 415-429.

Phytoplankton dynamics in the upper reach of the northern San Francisco Bay estuary are usually characterized by low biomass dominated by microflagellates or freshwater diatoms in winter, and high biomass dominated by neritic diatoms in summer. During two successive years of very low river discharge (the drought of 1976-77), the summer diatom bloom was absent. When river discharge falls within a critical range (100-50 m super(3) s super(1-)) that positions the suspended particulate maximum adjacent to the productive shallow bays, the population of neritic diatoms increases. However, during periods of high discharge (winter) or during periods of very low discharge (drought), the suspended particulate maximum is less well-defined and is uncoupled (positioned downstream or upstream) from the shallow bays of the upper estuary, and the population of neritic diatoms declines. Hence, the biomass and community composition of phytoplankton in this estuary are controlled by river discharge.

Cloern, J. E. (1979). Phytoplankton ecology of the San Francisco Bay system: The

status of our current understanding. San Francisco Bay: The urbanized estuary. T. J. Conomos. San Francisco, CA, American Association for the Advancement of Science, Pacific Division: 164-267 or 247-264??
Although past studies of phytoplankton dynamics in the San Francisco Bay system are limited in number and scope, they have provided sufficient information to define gross spatial and temporal patterns. Annual changes in the density and composition of phytoplankton populations differ among major geographic areas within the system, and recent studies suggest that phytoplankton dynamics in each major portion of San Francisco Bay are governed by a unique set of environmental factors. The annual maximum abundance of phytoplankton in central San Francisco Bay during spring may be a direct consequence of diatom blooms that occur in coastal waters during the upwelling season. The spring maximum of phytoplankton abundance in South Bay may also result from the dispersion of neritic diatoms from offshore during some years, although the 1978 spring maximum resulted from rapid in situ growth of microflagellate populations. Apparently, stratification of the South Bay water column (initiated by movement of Delta-derived low-density water from the northern reach) creates a shallow surface layer where flagellates are given sufficient solar irradiation to maintain rapid growth rates. Phytoplankton populations in the northern reach of San Francisco Bay apparently are most strongly regulated by the physical accumulation of suspended particulates by gravitational circulation, the rapid growth of planktonic algae over shoals, and phytoplankton dynamics in coastal waters and/or tributaries. Because few research efforts have been implemented to define environmental factors that regulate phytoplankton dynamics, basic unanswered (or unasked) questions remain. There is need (1) to define those functional groups of planktonic algae responsible for fixing inorganic carbon and energy, and then to follow pathways of energy and material transfer from the phytoplankton to other trophic levels, (2) to define the relationships between the physics of water movement and phytoplankton dynamics, and (3) to identify those physical-chemical-biological factors most responsible for regulating phytoplankton population size and composition, and then to quantify the response of algal population growth to changes in these important environmental factors

Cloern, J. E., and R.T. Cheng (1981). "Simulation model of Skeletonema costatum population dynamics in Northern San Francisco Bay, California." Estuarine, Coastal and Shelf Science 12(1): 83-100.
A pseudo-two-dimensional model is developed to simulate population dynamics of one dominant phytoplankton species (Skeletonema costatum) in northern San Francisco Bay. The model is formulated around a conceptualization of this estuary as two distinct but coupled subsystems—a deep (10–20 m) central channel and lateral areas with shallow (<2 m) water and slow circulation. Algal growth rates are governed by solar irradiation, temperature and salinity, while population losses are assumed to result from grazing bycalanoid copepods. Consequences of estuarine gravitational circulation are approximated simply by reducing convective-dispersive transport in that section of the channel (null zone) where residual bottom currents are near zero, and lateral mixing is treated as a bulkexchange process between the channel and the shoals. Model output is consistent with the hypothesis that, because planktonic algae are light-limited, shallow areas are the sites of active population growth. Seasonal variation in the location of the null zone (a response to variable river discharge) is responsible for maintaining the spring bloom of neritic diatoms in the seaward reaches of the estuary (San Pablo Bay) and the summer bloom upstream (Suisun Bay). Model output suggests that these spring and summer blooms result from the same general process—establishment of populations over the shoals, where growth rates are rapid, coupled with reduced particulate transport due to estuarine gravitational circulation. It also suggests, however, that the relative importance of physical and biological processes to phytoplankton dynamics is different in San Pablo and Suisun Bays. Finally, the model has helped us determine those processes having sufficient importance to merit further refinement in the next generation of models, and it has given new direction to field studies.

Cloern, J. E. (1982). "Does the benthos control phytoplankton biomass in south San Francisco Bay?" Marine Ecology Progress Series 9: 191-202.
South San Francisco Bay, USA, is a shallow coastal embayment that receives

large inputs of nutrients (N, P, Si) and small local inputs of freshwater. Phytoplankton dynamics are typically characterized by a spring bloom when surface chlorophyll a increases from < 5 to > 40 mg m-3. The bloom persists for 2 to 4 wk, and then dissipates. Phytoplankton biomass remains low (chlorophyll a < 5 mg m-3) from May through December, although light and nutrient availability are sufficient to sustain growth rates of 1 to 1.5 divisions d-' in the expansive shallows. Transport processes apparently exert a small influence on phytoplankton biomass, and calculated zooplankton grazing accounts for only a small reduction in net rate of phytoplankton population growth in the shallows. However, suspension-feeding bivalves are sufficiently abundant to filter a volume equivalent to the volume of South Bay at least once daily. These observations suggest that grazing by benthos is the primary mechanism controlling phytoplankton biomass during summer and fall.

Cloern, J. E., A. Alpine, B. Cole, R. Wong, J. Arthur, and M. Ball (1983). "River discharge controls phytoplankton dynamics in the northern San Francisco Bay Estuary." Estuarine, Coastal and Shelf Science 16(4): 415-429.

Phytoplankton dynamics in the upper reach of the northern San Francisco Bay estuary are usually characterized by low biomass dominated by microflagellates or freshwater diatoms in winter, and high biomass dominated by neritic diatoms in summer. During two successive years of very low river discharge (the drought of 1976-77), the summer diatom bloom was absent. This is consistent with the hypothesis that formation of the diatom population maximum is a consequence of the same physical mechanisms that create local maxima of suspended sediments in partially-mixed estuaries: density-selective retention of particles within an estuarine circulation cell. Because the estuary is turbid, calculated phytoplankton growth rates are small in the central deep channel but are relatively large in lateral shallow embayments where light limination is less severe. When river discharge falls within a critical range (100–350 m3 s–1) that positions the suspended particulate maximum adjacent to the productive shallow bays, the population of neritic diatoms increases. However, during periods of high discharge (winter) or during periods of very low discharge (drought), the suspended particulate maximum is less well-defined and is uncoupled (positioned downstream or upstream) from the shallow bays of the upper estuary, and the population of neritic diatoms declines. Hence, the biomass and community composition of phytoplankton in this estuary are controlled by river discharge.

Cloern, J. E. (1984). "Temporal dynamics and ecological significance of salinity stratification in an estuary (South San Francisco Bay, USA)." Oceanologica Acta 7: 137-141.

South San Francisco Bay (USA) has periodic variations in salinity stratification that coincide with neap-spring tidal variations during the winter "wet" season, but it remains well-mixed during summer and fall. The degree of salinity stratification, and timing of stratification events, can be predicted from a simple empirical function of river discharge and tidal current speed. During periods of prolonged salinity stratification, phytoplankton biomass and primary productivity are high, photoplankton patchiness increases, turbidity and nutrient (N) concentrations decline in the surface layer, and residual currents accelerate.

Cloern, J. E., B.E. Cole, R.L.J. Wong, and A.A. Alpine (1985). "Temporal dynamics of estuarine phytoplankton: a case study of San Francisco Bay." Hydrobiologia 129: 153-176.

Detailed surveys throughout San Francisco Bay over an annual cycle (1980) show that seasonal variations of phytoplankton biomass, community composition, and productivity can differ markedly among estuarine habitat types. For example, in the river-dominated northern reach (Suisun Bay) phytoplankton seasonality is characterized by a prolonged summer bloom of netplanktonic diatoms that results from the accumulation of suspended particulates at the convergence of nontidal currents (i.e. where residence time is long). Here turbidity is persistently high such that phytoplankton growth and productivity are severely limited by light availability, the phytoplankton population turns over slowly, and biological processes appear to be less important mechanisms of temporal change than physical processes associated with freshwater inflow and turbulent mixing. The South Bay, in contrast, is a lagoon-type estuary less directly coupled to the influence of river discharge.

Residence time is long (months) in this estuary, turbidity is lower and estimated rates of population growth are high (up to 1-2 doublings d-1), but the rapid production of phytoplankton biomass is presumably balanced by grazing losses to benthic herbivores. Exceptions occur for brief intervals (days to weeks) during spring when the water column stratifies so that algae retained in the surface layer are uncoupled from benthic grazing, and phytoplankton blooms develop. The degree of stratification varies over the neap-spring tidal cycle, so the South Bay represents an estuary where (1) biological processes (growth, grazing) and a physical process (vertical mixing) interact to cause temporal variability of phytoplankton biomass, and (2) temporal variability is highly dynamic because of the short-term variability of tides. Other mechanisms of temporal variability in estuarine phytoplankton include: zooplankton grazing, exchanges of microalgae between the sediment and water column, and horizontal dispersion which transports phytoplankton from regions of high productivity (shallows) to regions of low productivity (deep channels). Multi-year records of phytoplankton biomass show that large deviations from the typical annual cycles observed in 1980 can occur, and that interannual variability is driven by variability of annual precipitation and river discharge. Here, too, the nature of this variability differs among estuary types. Blooms occur only in the northern reach when river discharge falls within a narrow range, and the summer biomass increase was absent during years of extreme drought (1977) or years of exceptionally high discharge (1982). In South Bay, however, there is a direct relationship between phytoplankton biomass and river discharge. As discharge increases so does the buoyancy input required for density stratification, and wet years are characterized by persistent and intense spring blooms.

Cloern, J. E. (1987). "Turbidity as a control on phytoplankton biomass and productivity in estuaries." Est. Con. Shelf. Res. 7: 1367-1381.

In many coastal plain estuaries light attenuation by suspended sediments confines the photic zone to a small fraction of the water column, such that light limitation is a major control on phytoplankon production and turnover rate. For a variety of estuarine systems (e.g. San Francisco Bay, Puget Sound, Delaware Bay, Hudson River plume), photic-zone productivity can be estimated as a function of phytoplankton biomass times mean irradiance of the photic zone. Net water column productivity also varies with light availability, and in San Francisco Bay net productivity is zero (estimated respiratory loss of phytoplankton balances photosynthesis) when the ratio of photic depth (Zp) to mixed depth (Zm) is less than about 0.2. Thus whenever Zp: Zm < 0.2, the water column is a sink for phytoplankton production. Much of the spatial and temporal variability of phytoplankton biomass or productivity in estuaries is explained by variations in the ratio of photic depth to mixed depth. For example, phytoplankton blooms often coincide with stratification events that reduce the depth of the surface mixed layer (increase Zp: Zm). Shallow estuarine embayments (high Zp: Zm) are often characterized by high phytoplankton biomass relative to adjacent channels (low Zp: Zm). Many estuaries have longitudinal gradients in productivity that mirror the distribution of suspended sediments: productivity is low near the riverine source of sediments (low Zp: Zm) and increases toward the estuary mouth where turbidity decreases. Some of these generalizations are qualitative in nature, and detailed understanding of the interaction between turbidity and estuarine phytoplankton dynamics requires improved understanding of vertical mixing rates and phytoplankton respiration.

Cloern, J. E. (1991). Annual variations in river flow and primary production in the South San Francisco Bay estuary (USA). Estuaries and coasts: spatial and temporal intercomparisons. M. Elliott and J.-P. Ducrotoy. Fredensborg, Olsen and Olsen: 91-96.

Phytoplankton biomass and productivity in South San Francisco Bay are low except for periods of rapid increase that can occur in spring. The spring bloom is typically associated with density stratification of the water column that is induced by river flow. In the past decade of climatic and hydrologic extremes, the magnitude of the annual spring bloom (mean biomass and estimated primary production) was strongly correlated with the magnitude of river flow during the wet season. This investigation demonstrates one mechanism, of many, through which climatic and hydrologic variability can lead to variability of biological processes in estuaries.

Cloern, J. E. (1991). "Tidal stirring and phytoplankton bloom dynamics in an estuary." Journal of Marine Research 49(1): 203-221.
A decade of observation in South San Francisco Bay demonstrates that estuarine phytoplankton biomass fluctuates at the time scale of days to weeks, and that much of this variability is associated with fluctuations in tidal energy. During the spring seasons of every year from 1980-1990, episodic blooms occurred in which phytoplankton biomass rose from a baseline of 2-4 mg chlorophyll a m-3, peaked at 20-40 mg chlorophyll a m-3, and then returned to baseline values, all within several weeks. Each episode of biomass increase occurred during neap tides, and each bloom decline coincided with spring tides. This suggests that daily variations in the rate of vertical mixing by tidal stirring might control phytoplankton bloom dynamics in some estuaries. Simulation experiments with a numerical model of phytoplankton population dynamics support this hypothesis. The model incorporates biological processes (light-dependent growth, zooplankton grazing, benthic grazing) and physical processes (sinking, vertical mixing) as controls on the biomass distribution of phytoplankton in a 10-m water column. Numerical simulations indicate that phytoplankton dynamics are highly sensitive to the rate of vertical mixing (parameterized as an eddy diffusivity Kz), such that biomass increases rapidly at small Kz (5 m2 d-1), but not at large Kz (50 m2 d-1). Cyclic variation of Kz between 5 and 50 over a 14-d period (simulated neap-spring cycle) yields simulation results that are similar to bloom events observed in this estuary.

Cloern, J. E., B.E. Cole, and S.W. Hager (1994). "Notes on a Mesodinium rubrum red tide in San Francisco Bay (California, USA)." Journal of Plankton Research 16(9): 1269-1276.
Discrete red patches of water were observed in South San Francisco Bay (USA) on 30 April 1993, and examination of live samples showed that this red tide was caused by surface accumulations of the pigmented ciliate Mesodinium rubrum. Vertical profiles showed strong salinity and temperature stratification in the upper 5 m, peak chlorophyll fluorescence in the upper meter, and differences in the small-scale density structure and fluorescence distribution among red patches. Events preceding this Mesodinium red tide included: (i) heavy precipitation and run-off, allowing for strong salinity stratification; (ii) a spring diatom bloom where the chlorophyll a concentration reached 50 mg m–3; (ii) depletions of dissolved inorganic N and Si in the photic zone; and (iv) several days of rapid warming and stabilization of the upper surface layer. These conditions may be general prerequisites for M.rubrum blooms in temperate estuaries.

Cloern, J. E. (1996). "Phytoplankton bloom dynamics in coastal ecosystems: a review with some general lessons from sustained investigation of San Francisco Bay, California." Reviews of Geophysics 34: 127-168.
Phytoplankton blooms are prominent features of biological variability in shallow coastal ecosystems such as estuaries, lagoons, bays, and tidal rivers. Long-term observation and research in San Francisco Bay illustrates some patterns of phytoplankton spatial and temporal variability and the underlying mechanisms of this variability. Blooms are events of rapid production and accumulation of phytoplankton biomass that are usually responses to changing physical forcings originating in the coastal ocean (e.g., tides), the atmosphere (wind), or on the land surface (precipitation and river runoff). These physical forcings have different timescales of variability, so algal blooms can be short-term episodic events, recurrent seasonal phenomena, or rare events associated with exceptional climatic or hydrologic conditions. The biogeochemical role of phytoplankton primary production is to transform and incorporate reactive inorganic elements into organic forms, and these transformations are rapid and lead to measurable geochemical change during blooms. Examples include the depletion of inorganic nutrients (N, P, Si), supersaturation of oxygen and removal of carbon dioxide, shifts in the isotopic composition of reactive elements (C, N), production of climatically active trace gases (methyl bromide, dimethylsulfide), changes in the chemical form and toxicity of trace metals (As, Cd, Ni, Zn), changes in the biochemical composition and reactivity of the suspended particulate matter, and synthesis of organic matter required for the reproduction and growth of heterotrophs, including bacteria, zooplankton, and benthic consumer animals. Some classes of phytoplankton play special roles in the cycling of elements or synthesis of specific organic molecules,

but we have only rudimentary understanding of the forces that select for and promote blooms of these species. Mounting evidence suggests that the natural cycles of bloom variability are being altered on a global scale by human activities including the input of toxic contaminants and nutrients, manipulation of river flows, and translocation of species. This hypothesis will be a key component of our effort to understand global change at the land-sea interface. Pursuit of this hypothesis will require creative approaches for distinguishing natural and anthropogenic sources of phytoplankton population variability, as well as recognition that the modes of human disturbance of coastal bloom cycles operate interactively and cannot be studied as isolated processes.

Cloern, J. E. (1999). "The relative importance of light and nutrient limitation of phytoplankton growth: A simple index of coastal ecosystem sensitivity to nutrient enrichment." Aquatic Ecology 33(1): 3-16.
Anthropogenic nutrient enrichment of the coastal zone is now a well-established fact. However, there is still uncertainty about the mechanisms through which nutrient enrichment can disrupt biological communities and ecosystem processes in the coastal zone. For example, while some estuaries exhibit classic symptoms of acute eutrophication, including enhanced production of algal biomass, other nutrient-rich estuaries maintain low algal biomass and primary production. This implies that large differences exist among coastal ecosystems in the rates and patterns of nutrient assimilation and cycling. Part of this variability comes from differences among ecosystems in the other resource that can limit algal growth and production - the light energy required for photosynthesis. Complete understanding of the eutrophication process requires consideration of the interacting effects of light and nutrients, including the role of light availability as a regulator of the expression of eutrophication. A simple index of the relative strength of light and nutrient limitation of algal growth can be derived from models that describe growth rate as a function of these resources. This index can then be used as one diagnostic to classify the sensitivity of coastal ecosystems to the harmful effects of eutrophication. Here I illustrate the application of this diagnostic with light and nutrient measurements made in three California estuaries and two Dutch estuaries.

Cloern, J. E., T.S. Schraga, and C. Burns Lopez (2005). "Heat wave brings a red tide to San Francisco Bay." EOS Transactions of the American Geophysical Union 86(7): 66.

Cloern, J. E. (2007). "Habitat Connectivity and Ecosystem Productivity: Implications from a Simple Model." American Naturalist 169(1): E21-E33.
The import of resources (food, nutrients) sustains biological production and food webs in resource-limited habitats. Resource export from donor habitats subsidizes production in recipient habitats, but the ecosystem-scale consequences of resource translocation are generally unknown. Here, I use a nutrient-phytoplankton-zooplankton model to show how dispersive connectivity between a shallow autotrophic habitat and a deep heterotrophic pelagic habitat can amplify overall system production in metazoan food webs. This result derives from the finite capacity of suspension feeders to capture and assimilate food particles: excess primary production in closed autotrophic habitats cannot be assimilated by consumers; however, if excess phytoplankton production is exported to food-limited heterotrophic habitats, it can be assimilated by zooplankton to support additional secondary production. Transport of regenerated nutrients from heterotrophic to autotrophic habitats sustains higher system primary production. These simulation results imply that the ecosystem-scale efficiency of nutrient transformation into metazoan biomass can be constrained by the rate of resource exchange across habitats and that it is optimized when the transport rate matches the growth rate of primary producers. Slower transport (i.e., reduced connectivity) leads to nutrient limitation of primary production in autotrophic habitats and food limitation of secondary production in heterotrophic habitats. Habitat fragmentation can therefore impose energetic constraints on the carrying capacity of aquatic ecosystems. The outcomes of ecosystem restoration through habitat creation will be determined by both functions provided by newly created aquatic habitats and the rates of hydraulic connectivity between them.

Cloern, J. E., N. Knowles, L.R. Brown, D. Cayan, M.D. Dettinger, T.L. Morgan, D.H. Schoellhamer, M.T. Stacey, M. van der Wegen, R.W. Wagner, and A.D. Jassby (2011). "Projected Evolution of California's San Francisco Bay-Delta-River System in a Century of Climate Change." PLoS One 6(9): 13.

Cloern, J. E., A.D. Jassby, J. Carstensen, W.A. Bennett, W. Kimmerer, R. Mac Nally, D.H. Schoelhamer, M. Winder (2012). "Perils of correlating CUSUM-transformed variables to infer ecological relationships " Limnol. Oceanogr., 57(2), 2012, 665–668
E 2012, by the Association for the Sciences of Limnology and Oceanography, Inc. 57(2): 4.
We comment on a nonstandard statistical treatment of time-series data first published by Breton et al. (2006) in Limnology and Oceanography and, more recently, used by Glibert (2010) in Reviews in Fisheries Science. In both papers, the authors make strong inferences about the underlying causes of population variability based on correlations between cumulative sum (CUSUM) transformations of organism abundances and environmental variables. Breton et al. (2006) reported correlations between CUSUM-transformed values of diatom biomass in Belgian coastal waters and the North Atlantic Oscillation, and between meteorological and hydrological variables. Each correlation of CUSUM-transformed variables was judged to be statistically significant. On the basis of these correlations, Breton et al. (2006) developed ‘‘the first evidence of synergy between climate and human-induced river-based nitrate inputs with respect to their effects on the magnitude of spring Phaeocystis colony blooms and their dominance over diatoms.’’
Using the same approach, Glibert (2010) reported correlations between CUSUM-transformed abundances of organisms occupying many trophic levels and a range of environmental variables in the San Francisco Estuary, California. These correlations were reported to be statistically significant, and on this basis Glibert (2010) concluded that recent large population declines of diatoms, copepods, and several species of fish were responses to a single factor–increased ammonium inputs from a municipal wastewater treatment plant. The study by Breton et al. (2006) is consistent with a large body of research demonstrating the importance of climate and human activity on phytoplankton communities in Belgian coastal waters (Lancelot et al. 2007). However, Glibert’s (2010) study piqued our curiosity about correlations between CUSUM-transformed variables because it contradicts the overwhelming weight of evidence that population collapses of native fish (Sommer et al. 2007) and their supporting food webs in the San Francisco Estuary are responses to multiple stressors, including landscape change, water diversions, introductions of exotic species, and changing turbidity (Bennett and Moyle 1996; Kimmerer et al. 2005; Cloern 2007; Jassby 2008; Mac Nally et al. 2010; Thomson et al. 2010). We ask here how CUSUM transformation leads to inferences about such cause-effect relationships when visual inspection of the data series (e.g., Fig. 1) shows no association between wastewater ammonium and fish abundance.
We emphasize an important distinction between the CUSUM chart and CUSUM transformation. The CUSUM chart is a well-established technique of quality assurance for industrial processes (Page 1954). The method involves keeping a running summation of the deviations of the quality of the quantity of interest (e.g., concentration of an industrial chemical) based on a sample of size n. If the

quantity suddenly jumps, or gradually drifts from the specified tolerance, then a warning is raised and the process is stopped. The CUSUM chart has been used as a valuable off-line method in aquatic sciences to detect and resolve climatic (Breaker 2007) and ecological (Bricen˜o and Boyer 2010) regime shifts, as well as departures of water-quality indicators from compliance conditions (Mac Nally and Hart 1997). In contrast, there appears to be no history for regression (or correlation) analyses on CUSUM-transformed variables prior to its use by Breton et al. (2006), and we have found no theoretical development or justification for the approach. We prove here that the CUSUM transformation, as used by Breton et al. (2006) and Glibert (2010), violates the assumptions underlying regression techniques. As a result, high correlations may appear where none are present in the untransformed data (e.g., Fig. 1). Regression analysis on CUSUM-transformed variables is, therefore, not a sound basis for making inferences about the drivers of ecological variability measured in monitoring programs. This issue is sufficiently important to warrant exploration of the approach, which we present here.

Cloern, J. E., E. A. Canuel, et al. (2002). "Stable carbon and nitrogen isotope composition of aquatic and terrestrial plants of the San Francisco Bay estuarine system." Limnology and Oceanography 47: 713-729.

We report measurements of seasonal variability in the C-N stable isotope ratios of plants collected across the habitat mosaic of San Francisco Bay, its marshes, and its tributary river system. Analyses of 868 plant samples were binned into 10 groups (e.g., terrestrial riparian, freshwater phytoplankton, salt marsh) to determine whether C-N isotopes can be used as biomarkers for tracing the origins of organic matter in this river-marsh-estuary complex. Variability of 13C and 15N was high (~5-10‰) within each plant group, and we identified three modes of variability: (1) between species and their microhabitats, (2) over annual cycles of plant growth and senescence, and (3) between living and decomposing biomass. These modes of within-group variability obscure any source specific isotopic signatures, confounding the application of C-N isotopes for identifying the origins of organic matter. A second confounding factor was large dissimilarity between the 13C- 15N of primary producers and the organic matter pools in the seston and sediments. Both confounding factors impede the application of C-N isotopes to reveal the food supply to primary consumers in ecosystems supporting diverse autotrophs and where the isotopic composition of organic matter has been transformed and become distinct from that of its parent plant sources. Our results support the advice of others: variability of C-N stable isotopes within all organic-matter pools is high and must be considered in applications of these isotopes to trace trophic linkages from primary producers to primary consumers. Isotope-based approaches are perhaps most powerful when used to complement other tools, such as molecular biomarkers, bioassays, direct measures of production, and compilations of organic-matter budgets.

Cloern, J. E. and R. T. Cheng (1981). "Simulation model of Skeletonema costatum population dynamics in northern San Francisco Bay, California." Estuarine, Coastal and Shelf Science 12: 83-100.

A pseudo-two-dimensional model is developed to simulate population dynamics of one dominant phytoplankton species (Skeletonema costatum) in northern San Francisco Bay. The model is formulated around a conceptualization of this estuary as two distinct but coupled subsystems-a deep (10-20 m) central channel and lateral areas with shallow (<2m) water and slow circulation. Algal growth rates are governed by solar irradiation, temperature and salinity, while population losses are assumed to result from grazing by calanoid copepods.Consequences of estuarine gravitational circulation are approximated simply by reducing convective-dispersive transport in that section of the channel (null zone) where residual bottom currents are near zero, and lateral mixing is treated as a bulk exchange process between the channel and the shoals.

Cloern, J. E., B. E. Cole, et al. (1994). "Notes on a Mesodinium rubrum red tide in San Francisco Bay (California, USA)." Journal of Plankton Research 16: 1269-1276.
Discrete red patches of water were observed in South San Francisco Bay (USA) on 30 April 1993, and examination of live samples showed that this red tide was caused by surface accumulations of the pigmented ciliate Mesodinium rubrum. Vertical profiles showed strong salinity and temperature stratification in the upper 5 m, peak chlorophyll fluorescence in the upper meter, and differences in the small-scale density structure and fluorescence distribution among red patches. Events preceding this Mesodinium red tide included: (i) heavy precipitation and run-off, allowing for strong salinity stratification; (ii) a spring diatom bloom where the chlorophyll a concentration reached 50 mg m super(-3); (iii) depletions of dissolved inorganic N and Si in the photic zone; and (iv) several days of rapid warming and stabilization of the upper surface layer. These conditions may be general prerequisites for M. rubrum blooms in temperate estuaries.

Cloern, J. E. and R. Dufford (2005). "Phytoplankton community ecology: principles applied in San Francisco Bay." Marine Ecology Progress Series 285: 11-28.
In his seminal 1961 paper 'The paradox of the plankton' Am Nat 95:137-147, G. E. Hutchinson asked why many species of phytoplankton can coexist while competing for a small number of limiting resources in an unstructured habitat. Hutchinson anticipated the resolution of his paradox, recognizing that communities are organized by processes beyond resource competition including species interactions, habitat variability and dispersal. Since 1961 we have made fundamental discoveries that have revolutionized our conceptual understanding of pelagic ecology, including (1) habitat heterogeneity at all scales relevant to plankton population dynamics, (2) community shifts in response to global climate cycles, (3) fast and selective predation as a powerful top-down force to shape phytoplankton communities, (4) turbulent mixing as a physical process that selects species on the basis of their size and form, (5) mixotrophy that allows some algal species to tap organic nutrient pools and function at multiple trophic levels, (6) taxon-specific life cycles including alternating vegetative and resting stages, and (7) the pelagic as an open system where communities are continually reshaped by species immigration. Here we synthesize these discoveries to show how they validate and amplify Hutchinson's hypothesis that phytoplankton communities are assembled by many processes. Our synthesis is built around observations of phytoplankton species composition from a decade of study in San Francisco Bay, used as a case study to illustrate the contemporary principles of phytoplankton community ecology. We apply these principles to address 2 central questions: (1) What processes assemble phytoplankton communities? (2) How does phytoplankton community composition influence ecosystem functions such as production in pelagic and benthic food webs?.

Cloern, J. E., C. Grenz, et al. (1995). "An empirical model of the phytoplankton chlorophyll/carbon ratio -- the conversion factor between productivity and growth rate." Limnology and Oceanography 40(7): 1313-1321.
We present an empirical model that describes the ratio of phytoplankton chlorophyll a to carbon, Chl:C, as a function of temperature, daily irradiance, and nutrient-limited growth rate. Our model is based on 219 published measurements of algal cultures exposed to light-limited or nutrient-limited growth conditions. We illustrate an approach for using this estimator of Chl:C to calculate phytoplankton population growth rate from measured primary productivity. This adaptive Chl:C model gives rise to interactive light-nutrient effects in which growth efficiency increases with nutrient availability under low-light conditions. One implication of this interaction is the enhancement of phytoplankton growth efficiency, in addition to enhancement of biomass yield, as a response to eutrophication.

Cloern, J. E., K. A. Hieb, et al. (2010). "Biological communities in San Francisco Bay track large-scale climate forcing over the North Pacific." Geophysical Research Letters 37(21): L21602.

Cloern, J. E. and A. D. Jassby (1994). Year-to-year fluctuation in the spring phytoplankton bloom in South San Francisco Bay: An example of ecological variability at the land-sea interface. Ecological Time Series. J. H. Steele, T. M. Powell and S.

Levin. London, Chapman Hall: 139-149.

Cloern, J. E., A. D. Jassby, et al. (2007). "A cold phase of the East Pacific triggers new phytoplankton blooms in San Francisco Bay." Proceedings of the National Academy of Sciences, USA 104(47): 18561-18565.
Ecological observations sustained over decades often reveal abrupt changes in biological communities that signal altered ecosystem states. We report a large shift in the biological communities of San Francisco Bay, first detected as increasing phytoplankton biomass and occurrences of new seasonal blooms that began in 1999. This phytoplankton increase is paradoxical because it occurred in an era of decreasing wastewater nutrient inputs and reduced nitrogen and phosphorus concentrations, contrary to the guiding paradigm that algal biomass in estuaries increases in proportion to nutrient inputs from their watersheds. Coincidental changes included sharp declines in the abundance of bivalve mollusks, the key phytoplankton consumers in this estuary, and record high abundances of several bivalve predators: Bay shrimp, English sole, and Dungeness crab. The phytoplankton increase is consistent with a trophic cascade resulting from heightened predation on bivalves and suppression of their filtration control on phytoplankton growth. These community changes in San Francisco Bay across three trophic levels followed a state change in the California Current System characterized by increased upwelling intensity, amplified primary production, and strengthened southerly flows. These diagnostic features of the East Pacific "cold phase" lead to strong recruitment and immigration of juvenile flatfish and crustaceans into estuaries where they feed and develop. This study, built from three decades of observation, reveals a previously unrecognized mechanism of ocean-estuary connectivity. Interdecadal oceanic regime changes can propagate into estuaries, altering their community structure and efficiency of transforming land-derived nutrients into algal biomass.

Cloern, J. E. and F. H. Nichols, Eds. (1985). Temporal dynamics of an estuary: San Francisco Bay. Hydrobiologia. Dordrecht, Netherlands, Dr. W. Junk.
The purpose of this book is to examine the temporal dynamics of these properties and processes in the San
Francisco Bay estuary. Our approach is to (I) present our current understanding of the important time scales
of physical, geological, chemical, and biological change in the estuary, and (2) present hypotheses concerning
the processes responsible for causing these changes. The papers in this volume describe temporal dynamics of
individual components of the estuary and focus, where possible, on changes that occur over four time scales:
(I) the tidal cycle, (2) days to weeks, (3) months, and (4) between years. Ideally, we would like to understand
how all components change over all time scales. In reality, our understanding in some areas is limited by the
lack of comprehensive, long-term studies and / or the relative difficulty in achieving understanding of the
intricate interrelations among components of the estuarine system. Nonetheless, our compilation of all that is
known about temporal variability in this estuary has provided the opportunity to demonstrate how several
key driving forces affect individual components of the estuarine ecosystem.

Cloern, J. E. and F. H. Nichols (1985). "Time scales and mechanisms of estuarine variability, a synthesis from studies of San Francisco Bay." Hydrobiologia 129: 229-237.
This review of the preceding papers suggests that temporal variability in San Francisco Bay can be characterized by four time scales (hours, days-weeks, months, years) and associated with at least four mechanisms (variations in freshwater inflow, tides, wind, and exchange with coastal waters). The best understood component of temporal variability is the annual cycle, which is most obviously influenced by seasonal variations in freshwater inflow. The winter season of high river discharge is characterized by: large-scale redistribution of the salinity field (e.g. the upper estuary becomes a riverine system); enhanced density

stratification and gravitational circulation with shortened residence times in the bay; decreased tissue concentrations of some contaminants (e.g. copper) in resident bivalves; increased estuarine inputs of river-borne materials such as dissolved inorganic nutrients (N, P, Si), suspended sediments, and humic materials; radical redistributions of pelagic organisms such as copepods and fish; low phutoplankton biomass and primary productivity in the upper estuary; and elimination of freshwater-intolerant species of macroalgae and benthic infauna from the upper estuary. Other mechanisms modulate this river-driven annual cycle: (1) wind speed is highly seasonal (strongest in summer) and causes seasonal variations in atmosphere-water column exchange of dissolved gases, resuspension, and the texture of surficial sediments; (2) seasonal variations in the coastal ocean (e.g. the spring-summer upwelling season) influence species composition of plankton and nutrient concentrations that are advected into the bay; and (3) the annual temperature cycle influences a few selected features (e.g. production and hatching of copepod resting eggs). Much of the interannual variability in San Francisco Bay is also correlated with freshwater inflow: wet years with persistently high river discharge are characterized by persistent winter-type conditions. Mechanisms of short-term variability are not as well understood, although some responses to storm events (pulses in residual currents from wind forcing, erosion of surficial sediments by wind waves, redistribution of fish populations) and the neap-spring tidal cycle (enhanced salinity stratification, gravitational circulation, and phytoplankton biomass during neap tides) have been quantified. In addition to these somewhat predictable features of variability are (1) largely unexplained episodic events (e.g. anomalous blooms of drift macroalgae), and (2) long-term trends directly attributable to human activities (e.g. introduction of exotic species that become permanent members of the biota).

Cloern, J. E. and R. S. Oremland (1983). "Chemistry and microbiology of a sewage spill in south San Francisco Bay." Estuaries 6: 399-406.
During three weeks of September 1979, the breakdown of a waste treatment plant resulted in the discharge of a large volume (1.5 x 10 super(7) m super(3)) of primary-treated sewage into a tributary of South San Francisco Bay, California. Chemical and microbial changes occurred within the tributary as decomposition and nitrification depleted dissolved oxygen. Associated with anoxia were relatively high concentrations of particulate organic carbon, dissolved CO sub(2), CH sub(4), C sub(2)H sub(4), NH sub(4) super(+), and fecal bacteria, and low phytoplankton biomass and photosynthetic oxygen production. South San Francisco Bay experienced only small changes in water quality, presumably because of its large volume and the assimilation of wastes that occurred within the tributary. Water quality improved rapidly in the tributary once normal tertiary treatment resumed.

Cloern, J. E., T. M. Powell, et al. (1989). "Spatial and temporal variability in South San Francisco Bay (USA). 2. Temporal changes in salinity, suspended sediments, and phytoplankton biomass and productivity over tidal time scales." Estuarine, Coastal, and Shelf Science 28: 599-613.
Short-term variability of a conservative quantity (salinity) and two nonconservative quantities (chlorophyll a, suspended particulate matter) was measured across a sampling grid in the South San Francisco Bay estuary. Surface measurements were made every 2 h at each of 29 (or 38) sites, on four different dates representing a range of tidal current regimes over the neap-spring cycle. From the distribution of phytoplankton biomass (chlorophyll a) and turbidity (SPM), we also estimated daily productivity and its variability at each site over the four tide cycles. As a general rule, both chlorophyll a and SPM concentrations varied about 50% from their tidal-means. However derived daily productivity varied less (about 15% from the mean) over a tidal cycle. Both chlorophyll a and SPM varied periodically with tidal stage (increasing on ebbing currents), suggesting that the short-term variability results simply from the tidal advection of spatial gradients. Calculation of the advective flux (current speed times spatial gradient) was used to test this hypothesis. For surface salinity, most (70–80%) of the observed intratidal variability was correlated with the tidal flux, both in the deep channel and over the lateral shoals. However the short-term variability of SPM concentration was only weakly correlated with the advective flux, indicating that local sources of SPM (resuspension) are important. Hourly changes in chlorophyll a were highly correlated

with the advective flux in the deep channel (implying that phytoplankton biomass is conservative over short time scales there); however, chlorophyll a variability was only weakly correlated with the advective flux over the shoals, implying that local sources/sinks are important there. Hence, the magnitude and mechanisms of intratidal variability differ among constituents and among bathymetric regimes in this estuary.

Cloern, J. E., T. S. Schraga, et al. (2005). "Climate anomalies generate an exceptional dinoflagellate bloom in San Francisco Bay." Geophysical Research Letters 32(L14608): 5.

We describe a large dinoflagellate bloom, unprecedented in nearly three decades of observation, that developed in San Francisco Bay (SFB) during September 2004. SFB is highly enriched in nutrients but has low summer-autumn algal biomass because wind stress and tidally induced bottom stress produce a well mixed and light-limited pelagic habitat. The bloom coincided with calm winds and record high air temperatures that stratified the water column and suppressed mixing long enough for motile dinoflagellates to grow and accumulate in surface waters. This event-scale climate pattern, produced by an upper-atmosphere high-pressure anomaly off the U. S. west coast, followed a summer of weak coastal upwelling and high dinoflagellate biomass in coastal waters that apparently seeded the SFB bloom. This event suggests that some red tides are responses to changes in local physical dynamics that are driven by large-scale atmospheric processes and operate over both the event scale of biomass growth and the antecedent seasonal scale that shapes the bloom community.

Cloern, J. E. a. A. D. J. (2008). "Complex seasonal patterns of primary producers at the land-sea interface." Ecology Letters 11: 10.

Cloern, J. E. a. A. D. J. (2009). "Patterns and scales of phytoplankton variability in estuarine-coastal ecosystems." Estuaries and Coasts 33: 12.

Phytoplankton variability is a primary driver of chemical and biological dynamics in the coastal zone because it directly affects water quality, biogeochemical cycling of reactive elements, and food supply to consumer organisms. Much has been learned about patterns of phytoplankton variability within individual ecosystems, but patterns have not been compared across the diversity of ecosystem types where marine waters are influenced by connectivity to land. We extracted patterns from chlorophyll-a series measured at 84 estuarine–coastal sites, using a model that decomposes time series into an annual effect, mean seasonal pattern, and residual “events.” Comparisons across sites revealed a large range of variability patterns, with some dominated by a recurrent seasonal pattern, others dominated by annual (i.e., year-to-year) variability as trends or regime shifts and others dominated by the residual component, which includes exceptional bloom events such as red tides. Why is the partitioning of phytoplankton variability at these three scales so diverse? We propose a hypothesis to guide next steps of comparative analysis: large year-to-year variability is a response to disturbance from human activities or shifts in the climate system; strong seasonal patterns develop where the governing processes are linked to the annual climate cycle; and large event-scale variability occurs at sites highly enriched with nutrients. Patterns of phytoplankton variability are therefore shaped by the site-specific relative importance of disturbance, annual climatology, and nutrient enrichment.

Cloern, J. E. a. A. D. J. (2012). "Drivers of change in estuarine-coastal ecosystems: discoveries from four decades of study in San Francisco Bay." Reviews of Geophysics 50(RG4001): 33.

[1] Poised at the interface of rivers, ocean, atmosphere and dense human settlement, estuaries are driven by a large array of natural and anthropogenic forces. San Francisco Bay exemplifies the fast-paced change occurring in many of the world’s estuaries, bays, and inland seas in response to these diverse forces. We use observations from this particularly well-studied estuary to illustrate responses to six drivers that are common agents of change where land and sea meet: water consumption and diversion, human modification of sediment supply, introduction of nonnative species, sewage

input, environmental policy, and climate shifts. In San Francisco Bay, responses to these drivers include, respectively, shifts in the timing and extent of freshwater inflow and salinity intrusion, decreasing turbidity, restructuring of plankton communities, nutrient enrichment, elimination of hypoxia and reduced metal contamination of biota, and food web changes that decrease resistance of the estuary to nutrient pollution. Detection of these changes and discovery of their causes through environmental monitoring have been essential for establishing and measuring outcomes of environmental policies that aim to maintain high water quality and sustain services provided by estuarinecoastal ecosystems. The many time scales of variability and the multiplicity of interacting drivers place heavy demands on estuarine monitoring programs, but the San Francisco Bay case study illustrates why the imperative for monitoring has never been greater.

Cohen, A. N., and J.T. Carlton (1998). "Accelerating invasion rate in a highly invaded estuary." Science 279: 555-558.

Biological invasions are a major global environmental and economic problem. Analysis of the San Francisco Bay and Delta ecosystem revealed a large number of exotic species that dominate many habitats in terms of number of species, number of individuals and biomass, and a high and accelerating rate of invasion. These factors suggest that this may be the most invaded estuary in the world. Possible causes include a large number and variety of transport vectors, a depauperate native biota, and extensive natural and anthropogenic disturbance.

Cohen, A. N. (2010). The history of native oysters in San Francisco Bay: Implications for restoration. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Federal- and state-funded efforts to restore native oysters (Ostrea lurida) in San Francisco Bay started in 1999, and plans and goals are now being developed for the large-scale creation of oyster beds in the Bay. These efforts are predicated on the well-known and oft-repeated history of the native oyster: it was hugely abundant in the Bay at the time of European contact, providing an important food source for the region’s Native American inhabitants as shown by the accumulation of oyster shells in the Bay’s shell mounds; it declined rapidly during the early colonial period due to a combination of overharvesting, pollution, and smothering by hydraulic mining sediment; and then it was apparently absent for decades until its rediscovery in the late 1990s, which initiated the current restoration efforts. However, a review of the historical, archaeological and geological evidence calls this common understanding of the history of the native oyster into question: virtually everything in this history is unsupported by the available physical and historical data. Restoration efforts have been successful when there is good evidence of the level of past abundance, a clear understanding of what anthropogenic stressors have reduced that past abundance, and a sufficient capacity to end or undo the effects of those stressors. All of this appears to be lacking in the case of the Bay’s native oysters, which suggests that the existing restoration projects and the plans and goals being developed should be reconsidered.

Cohen, A. N. (2010). Quagga and zebra mussels in the western U.S.: Invasion and response 2007-2010. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Quagga and zebra mussels, native to Europe, were discovered in the Great Lakes in the 1980s, with zebra mussels subsequently spreading widely in eastern North America. Impacts on the lower Great Lakes and other water bodies have been large and various, including alterations of food webs, light penetration and water chemistry, with associated reductions in the populations of native bivalves, benthic amphipods and fish. Economic impacts are typically estimated in the hundreds of millions to billions of dollars, and include impacts on water supplies, commercial and recreational fishing, other water-based recreation, navigation, and property values. Both mussels were discovered in the western U.S. in 2007/08. This

presentation will describe the mussels' current western distribution; the potential for environmental factors, especially calcium concentrations, to limit their distribution in the Delta watershed; monitoring efforts; the controversy over reports of larval detection (by microscopy and molecular genetic assays) in Western water bodies, including the likelihood that at least some of the reported detections are false positives; interception, containment and eradication efforts; and will present a protective strategy that focuses on more effective containment.

Cohen, A. N. (2010). A re-assessment of the historic changes in sediment flows into San Francisco Bay. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
There is good deal of interest in understanding how sediment flows into San Francisco Bay have changed relative to historic and natural conditions. These changes can affect dredging needs, erosion rates, the re-suspension of buried contaminants, tidal marsh restoration efforts and the capacity of the Bay to support oyster and eelgrass beds. They also provide a benchmark for assessing projected impacts from climate change. The Bay sediment literature uniformly quotes estimates from Grove Karl Gilbert's 1917 monograph on hydraulic mining debris as the baseline for natural (pre-1850) and peak historic (roughly the last half of the 19th century) sediment flows into the Bay. However, a review of Gilbert's sediment budget model reveals that his estimates have been misquoted since he does not actually provide a value for historic sediment inflow to the Bay, nor can a specific value be calculated from his data (though rough upper and lower bounds can be determined). More critically, however, incorrect values for bulk sediment density have been used to convert Gilbert's sediment volume estimates to mass units for comparison with modern sediment flow measurements, thereby substantially understating Gilbert's sediment flow estimates, possibly by a factor of 3-5. Overall, the baseline estimates of natural and peak historic sediment inflows are much higher and more uncertain than recent literature has indicated, which greatly alters our perception of both where we are today and where we are headed relative to baseline conditions. This in turn affects our understanding of how shifts in sediment inflows due to dams, diversions, channel alterations, land use, climate change or other anthropogenic factors may affect shoreline erosion, the ecosystem's exposure to legacy contaminants, and the potential to achieve certain types of environmental restoration or enhancement.

Cohen, A. N. and J. T. Carlton (1995). Nonindigenous aquatic species in a United States estuary: A case study of the biological invasions of the San Francisco Bay and Delta, U.S. Fish and Wildlife Service Report.: 246pp.

Cohen, A. N. and J. T. Carlton (1998). "Accelerating invasion rate in a highly invaded estuary." Science 279: 555-558.
Biological invasions are a major global environmental and economic problem. Analysis of the San Francisco Bay and Delta ecosystem revealed a large number of exotic species that dominate many habitats in terms of number of species, number of individuals and biomass, and a high and accelerating rate of invasion. These factors suggest that this may be the most invaded estuary in the world. Possible causes include a large number and variety of transport vectors, a depauperate native biota, and extensive natural and anthropogenic disturbance.

Cohen, A. N., J. T. Carlton, et al. (1995). "Introduction, dispersal and potential impacts of the green crab Carcinus maenas in San Francisco Bay, California." Marine Biology 122(2): 225-237.
The North Atlantic portunid crab Carcinus maenas has invaded the North Pacific Ocean following more than two centuries of global dispersal due to human activities. C. maenas was first collected in San Francisco Bay, California, in 1989-1990, where its distribution and prey selectivity were investigated in 1992-1994. It has become abundant in shallow, warm lagoons (which as favorable and retentive microhabitats may have served as invasion incubators) and spread throughout the north, central and south bays. It may have arrived in ballast water, on fouled ships, amongst algae with imported live bait or lobsters, or by intentional release; genetic comparisons of the Bay population with possible source populations may aid in defining the transport mechanism. C. maenas' eurytopic

nature, its high breeding potential, and its diet and feeding behavior suggest the potential for extensive ecosystem alterations through predator-prey interactions, competition, disturbance, and indirect effects. Although both negative economic impacts through reduction or disruption of fisheries and positive impacts of providing bait and human-food fisheries have been documented in a few regions, the potential economic impacts in San Francisco Bay remain largely unknown.

Cohen, S. E. and S. M. Bollens (2008). "Diet and growth of non-native Mississippi silversides and yellowfin gobies in restored and natural wetlands in the San Francisco Estuary." Marine Ecology Progress Series 368: 241-254.

We examined how wetland restoration status influenced habitat quality for fishes by comparing otolith-calculated growth rates and diets of 2 abundant non-native fish species, the locally transient planktivorous Mississippi silverside Menidia audens and the resident demersal-feeding yellowfin goby Acanthogobius flavimanus, in 2 wetlands undergoing restoration ('restoring' wetlands) and 1 natural wetland (Napa River, San Francisco Estuary, California, USA; 38 degrees 10'N; 122 degrees 18'W). Native species with similar trophic requirements were too few in abundance to serve as study organisms. Differences in fish diet and growth based on restoration status were expected for the more resident goby species, but not for the transient silversides. Fish were collected in June 2004 and 2005 from a 10 yr old restoring marsh, a 50 yr old restoring marsh and a natural marsh, using a modified fyke net. Diet of silversides was primarily composed of copepods, cumaceans, and flying insects, while yellowfin goby diets were composed of annelids, cumaceans, and amphipods. Prey species biomass in the stomachs of yellowfin gobies was significantly different between marshes, but. these differences were not dependent on restoration status. No significant differences in Mississippi silverside growth rates were detected, and yellowfin goby growth rates varied somewhat between marshes and years, but were not significantly different between restored versus reference sites. Based on these findings, we suggest that adequate prey abundance and prey species composition is available for these fish species in both our restored and natural study sites. It also appears that some restoring breached wetlands can quickly (within 10 yr) provide equivalent habitat to natural areas, at least for generalist, non-native fishes; however, consideration of underlying mechanisms of restoration will be important in designing wetlands that specifically favor native fish populations.

Colby, D. (2010). Longer-term observations related to sustainability of stream channel restoration in Clear Creek: Juvenile salmonid habitat use. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The CALFED and CVPIA funded Lower Clear Creek Floodway Rehabilitation Project is a multi-phase project, designed to restore 2.5 miles of stream channel and floodplain habitat. While the project met its adult habitat goals, we evaluated the secondary, juvenile-habitat goal of the project. Clear Creek is a high priority watershed for CALFED, which has funded similar large-scale restoration projects in other watersheds. Direct measurement of juvenile densities has rarely been performed in these other projects. We evaluated two objectives: 1) attain average juvenile densities equal to or greater than control reaches, and 2) retain juvenile habitats for at least 5 years, with juvenile densities twice those in the control reaches. We conducted habitat use surveys in the spring of 2003, 2005, 2008 and 2010 to evaluate the affect of the project on juvenile Chinook densities. Our study focused on Phases 3A and 3B, which were completed in 2002 and 2007 respectively. The survey area included two restoration phases and two control reaches. We estimated Chinook numbers from underwater snorkel observations. We compared fish densities by reach, restored versus unrestored, incorporated habitat features and presence of adjacent riparian vegetation, using ANOVA and pairwise comparisons. Overall, juvenile densities were lower in restoration areas than in controls. While high juvenile densities were sustained in Phase 3A, Phase 3B would benefit from additional instream work. Phase 3B had significantly lower juvenile densities than other reaches in part because performance of revetment rootwads in 3B declined. We examined how differences in design, implementation or evolution of the rootwads may result in differences in habitat structure, complexity, water velocity and sustainability. The 3B rootwads and poor quality habitats would be improved by adding suitable substrate, submerged shoreline vegetation, and additional woody debris. This monitoring will be useful in adapting this and future projects.

Cole, B., S.M. Brander, D. Sedlak, D. Schlenk, B. Bernis, J. Johnson, and G. Cherr (2010). Use of a resident fish for assessment of endocrine disruption at selected sites in the Sacramento-San Joaquin Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Here we present the development of Menidia beryllina, the Atlantic Silverside, for use as a bioindicator of the presence of estrogenic endocrine disrupting compounds. Two sites within the Sacramento-San Joaquin Delta were chosen for this assay: the Napa River and Walnut Grove on the Sacramento River. This assay detects the presence of the inappropriate expression of the choriogenin protein via a polyclonal antibody specific to Menidia. Choriogenin is not normally produced in juvenile or male fish, therefore its presence is indicative of exposure to estrogenic compounds in the water. For example, previous exposures to pyrethroid pesticides in the laboratory showed induction of choriogenins in Menidia. The purpose of this study was to assess choriogenins in Menidia from Delta field sites as well as in cultured juvenile Menidia exposed to site water in the laboratory. Adult males were seined from each site. Juvenile fish were exposed to water collected from each site, or to clean spring water as a control, for two weeks with daily renewal under laboratory conditions. Whole-body homogenates from lab-exposed juveniles and plasma from field-collected adults were then analyzed for presence of choriogenin. Results will be part of a larger study that also assessed vitellogenin response in medaka and rainbow trout tissues/cells following exposure to water from the same sites. Expression of choriogenin in these resident fish appears to be a useful indicator of exposure to estrogenic compounds in Delta waters, and can likely be utilized in other areas, as Menidia are found in rivers and estuaries nationwide.

Cole, B. E., and J.E. Cloern (1987). "An empirical model for estimating phytoplankton productivity in estuaries." Marine Ecology Progress Series 36: 299-305.
We have previously shown that primary productivity in San Francisco Bay, USA, is highly correlated with phytoplankton biomass B (chlorophyll a concentration) and an index of light availability in the photic zone, ZpIo (photic depth times surface irradiance). To test the generality of this relation, we compiled data from San Francisco Bay and 5 other USA estuarine systems (Neuse and South Rivers, Puget Sound, Delaware Bay and Hudson River Plume), and regressed daily productivity against the composite parameter B ZpIo. Regressions for each estuary were significant and typically over 80 % of the variation in 5 P was correlated with variations in B ZpIo. Moreover, the pooled data (n=211) from 4 estuaries where methodologies were comparable fell along one regression line (r2= 0.82), indicating that primary productivity can be estimated in a diversity of estuarine waters from simple measures of phytoplankton biomass and light availability. This implies that physiological variability (e.g. responses to variations in nutrient availability, temperature, salinity, photoperiod) is a secondary control on phytoplankton production in nutrient rich estuaries, and that one empirical function can be used to estimate seasonal variations in productivity or to map productivity along estuarine gradients of phytoplankton biomass and turbidity.

Cole, B. E. and J. E. Cloern (1984). "Significance of biomass and light availability to phytoplankton productivity in San Francisco Bay." Marine Ecology Progress Series 17: 15-24.
Primary productivity was measured monthly at 6 sites within San Francisco Bay, USA, throughout 1980. The sites were chosen to represent a range of estuarine environments with respect to salinity, phytoplankton community composition, turbidity, and water depth. Annual net production over the photic zone ranged from 95 to 150 C m super(-2), and was highest in regions of lowest turbidity. Daily photic zone net productivity PN sub(pd) ranged from 0.05 to 2.2 g C m super(-2) d super(-1), and was significantly correlated with the composite parameter B I sub(o)/ epsilon (where B = phytoplankton biomass; I sub(o) = daily surface insolation; epsilon = attenuation coefficient). Linear regression of PN sub(pd) against B I sub(o)/ epsilon indicated that most (82%) of the spatio-temporal variability in

primary productivity within this estuary is explained by variations in light availability and phytoplankton biomass.

Cole, B. E. and J. E. Cloern (1987). "An empirical model for estimating phytoplankton productivity in estuaries." Marine Ecology Progress Series 36: 299-305.
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productivity along estuarine gradients of phytoplankton biomass and turbidity.

Cole, B. E., J. E. Cloern, et al. (1986). "Biomass and productivity of three phytoplankton size classes in San Francisco Bay." Estuaries and Coasts 9: 117-126.

Primary productivity of three size classes of phytoplankton (<5 μm, 5–22 μm, >22 μm) was measured monthly at six sites within San Francisco Bay throughout 1980. These sites in the three principal embayments were chosen to represent a range of environments, phytoplankton communities, and seasonal cycles in the estuary. Temporal variations in productivity for each size class generaly followed the seasonality of the corresponding fraction of phytoplankton biomass. The 5–22 μm size class accounted for 40 to 50% of the annual production in each embayment, but production by phytoplankton >22 μm ranged from 26% in the southern reach to 54% of total phytoplankton production in the landward embayment of the northern reach. A productivity index is derived that predicts daily productivity for each size class as a function of ambient irradiance and integrated chlorophylla in the photic zone. For the whole phytoplankton community and for each size class, this index was constant and estimated as 0.76 g C m–2 (g chlorophylla Einstein)–1. The annual means of maximum carbon assimilation numbers were usually similar for the three size classes. Spatial and temporal variations in size-fractionated productivity are shown to be primarily due to differences in biomass rather than size-dependent carbon assimilation rates.

Cole, B. E., J. K. Thompson, et al. (1992). "Measurement of Filtration Rates by Infaunal Bivalves in a Recirculating Flume." Marine Biology 113(2): 219-225.
A flume system and protocol for measuring the filtration rate of infaunal bivalves is described. Assemblages of multi-sized clams, at natural densities and in normal filter-feeding positions, removed phytoplankton suspended in a unidirectional flow of water. The free-stream velocity and friction velocity of the flow, and bottom roughness height were similar to those in natural estuarine waters. Continuous variations in phytoplankton (Chroomonas salinay) cell density were used to measure the filtration rate of the suspension-feeding clam Potamocorbula amurensis for periods of 2 to 28 h. Filtration rates of P. amurensis varied from 100 to 580 liters/(gd) over a free-stream.

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Collignon, A., C. Holleman, A. Brand, J.R. Lacy, M.T. Stacey (2010). Development of a transverse circulation in a shoal-channel system under partially stratified conditions. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
In San Francisco Bay like in many other estuaries, abrupt lateral changes in topography result in sharp transverse gradients of momentum and scalars. These strong gradients both drive and respond to transverse mixing processes, including turbulent diffusive exchange, coherent transverse circulations and event-driven exchanges that may develop within the tidal cycle. Each of these three cases is characterized by a different timescale for the mixing of shoal-channel water masses, with implications for larger scale estuarine transport and dispersion. In particular, these processes have a strong influence on sediment fluxes and redistribution in a shoal-channel estuary like San Francisco Bay. In this talk, we examine shoal-channel exchange directly using transect data with 30 minutes resolution to follow the evolution of longitudinal and transverse velocity and density throughout the tidal cycle. During the winter period, our study site in South San Francisco Bay is characterized by moderate salinity variations, including periodic partial stratification. In this season, we find that a strong transverse density gradient develops during the ebb tide. Late in the ebb, barotropic tidal flows in the shallows are directed obliquely to the channel, where the relatively dense shoal waters meet less dense channel waters. This convergence leads to the downwelling of shoal waters down the slope, which stratifies the edge of the channel. This lateral exchange mechanism, which relies on lateral density gradients and barotropic tidal forcing, would be expected to develop in many shoal-channel estuaries. Finally, using longer timeseries from adjacent moorings, we examine the repeatability and longer-term implications of this mechanism for shoal-channel exchange.

Collins, B. W. (1982). "Growth of Adult Striped Bass in the Sacramento-San Joaquin Estuary." California Fish and Game 68(3): 146-159.
Adult striped bass, Morone saxatilis, growth in the Sacramento-San Joaqin Estuary was described well by the von Bertalanffy growth equation. After age 3, females grew more rapidly than males and by age 6 they were as large as 7-yr-old males. The size bass attain as adults appeared to be affected by their growth rate as young-of-the-year. An average 2 cm decrease in adult length was associated with an 18% decrease in young bass growth rate commencing in 1970. Annual mean growth in

1971 was substantially higher than for any other year and was associated with abundant forage in San Francisco and San Pablo bays.

Colt, J. (1984). "Seasonal changes in dissolved-gas supersaturation in the Sacramento River (California, USA) and possible effects on striped bass (Morone saxatilis)." Transactions of the American Fisheries Society 113(5): 655-665.
During 1981-1982, dissolved-gas supersaturation levels were monitored in the Sacramento River system in central California. Gas supersaturation was highest in the spring when temperature and flow were increasing rapidly, and was caused primarily by inflows of highly supersaturated water from the American and Feather rivers. Entrainment of air at dams does not appear to be responsible for gas supersaturation in these two rivers. Gas supersaturation in the Sacramento-San Joaquin River system may adversely affect the eggs and larvae of wild striped bass Morone saxatilis and salmonids in hatcheries.

Colwell, M. A., and O.W. Taft (2000). "Waterbird communities in managed wetlands of varying water depth." Waterbirds 23(1): 45-55.
Published accounts of interspecific differences in habitat use by waterbirds predict that shallow wetlands should accommodate more species and greater numbers of waterbirds than deep wetlands. We evaluated this hypothesis by examining relationships between winter (January/February) waterbird use (presence/absence, density and number of species) and average depth, variation in depth and size of 25 wetlands in the northern San Joaquin Valley, California. Bird densities correlated consistently with depth. Likelihood of use increased in shallow wetlands for all nine wading birds (shorebirds and ibis); densities of three dabbling duck species and Black-necked Stilt (Himantopus mexicanus) also increased in shallow wetlands, whereas use and densities of two diving birds increased in deep wetlands. We observed no statistically significant relationship between depth and densities of two other waterbird species. The number of species of waterbird, dabbling duck, and wading bird increased in shallow wetlands, whereas the number of species of diving bird increased in deep wetlands. Wetland size and topographic variation inconsistently predicted waterbird densities, but both characteristics correlated positively with number of species. Our results provide general support for shallow flooding of wetlands to provide habitat for more species. We conclude that managers seeking to provide foraging habitat for a diverse community of wintering waterbirds should flood wetlands to average depths of 10-20 cm, where topography can provide a range of depths attractive to a large number of species. However, this prescription is region-specific and influenced by the great diversity and abundance of waterfowl and shorebirds wintering in California's Central Valley.

Conaway, C. H., J. R. M. Ross, et al. (2007). "Decadal mercury trends in San Francisco Estuary sediments." Environmental Research 105(1): 53-66.
Monitoring sediment quality and total mercury concentrations over the period 1993-2001 at 26 stations in San Francisco Estuary has shown the seasonal cycling of mercury sediment concentrations, as well as a significant (P<0.05) decrease in those concentrations at eight stations across the estuary. This decrease in sediment mercury concentrations is attributed to the transport of relatively cleaner sediment to the estuary from the Sacramento River and San Joaquin River watersheds. Despite the decreases observed in some parts of the estuary, no corresponding trend has been found in concurrent studies on sport fish and bivalves in the estuary.

Conaway, C. H., S. Squire, et al. (2003). "Mercury speciation in the San Francisco Bay estuary." Marine Chemistry 80: 2-3.
In order to understand the biogeochemistry of mercury in the San Francisco Bay estuary, California, we undertook a 2-year study of sediments and surface waters to investigate sources of mercury to the estuary and the processes that control its distribution. Over several seasons, unfiltered and filtered (0.45 mu m) surface water samples were collected from 26 sites in the estuary and analyzed for total mercury (HgT), monomethylmercury (MMHg), and ancillary water quality parameters. Concentrations of mercury in unfiltered surface water UHgT ranged from 0.73 to 440 pM, and were well correlated with suspended particulate matter (SPM). Concentrations of UHgT were typically highest in the winter and spring, when precipitation, fluvial discharges, and SPM were greatest. Although the concentrations of UHgT appear

elevated with respect to other contaminated estuaries, this is largely explained by the high SPM in this system. The average concentration of mercury in suspended particles was 1.8 plus or minus 0.6 nmol g super(-1), and was similar to the concentration of HgT in sediments (1.1 plus or minus 0.7 nmol g super(-1)), especially when normalized to grain size (%63 mu m; 1.7 plus or minus 0.7 nmol g super(-1)), demonstrating the preferential resuspension of fine-grained sediment, and the importance of wind and tidal driven resuspension in controlling UHgT concentrations. Concentrations of dissolved gaseous mercury averaged 0.90 plus or minus 0.88 pM, and the estuary was a net source of mercury to the atmosphere of 40-240 kg year super(-1). The concentrations of surface water MMHg ranged from 0.050 to 2.3 pM, and appeared to be controlled by input from the Sacramento-San Joaquin delta in the northern reach and by wastewater inputs in the extreme southern reach. Sediment mercury concentrations were significantly correlated with the fraction of fine-grained material present and the concentrations of total organic carbon. Concentrations of MMHg in the sediments ranged from 0.5 to 5.0 pmol g super(-1), with an average of about 2 pmol g super(-1); the highest concentrations were found in areas with detectable pore water sulfide, high nutrient input from wastewater, and low salinity. Although the mercury in this system is principally attributed to contamination from historic mining activity, concentrations were similar to those of other large, urbanized estuaries that are primarily contaminated with recent industrial inputs.

Conaway, C. H., E. B. Watson, et al. (2004). "Mercury deposition in a tidal marsh of south San Francisco Bay downstream of the historic New Almaden mining district, California." Marine Chemistry 90(1-4): 175-184.

A record of mercury deposition was provided by sediment recovered from piston cores of a south San Francisco Bay tidal marsh that is 30 km downstream of the New Almaden mining district, formerly the largest mercury mining district in North America. Pre-mining sediment mercury concentrations were 0.40 +/- 0.15 nmol g-1, which are similar to pre-mining concentrations in cores taken from other parts of San Francisco Estuary. Concentrations in the core increase to a maximum of about 6.0 nmol g-1, corresponding to a period in the mid-20th century, nearly 50 years after the peak in mercury production at the mines. The extent of contamination from upstream mining activity appears to reflect the amount of processed ore disposed of at the surface, and also periods when mercury was recovered from reworking these surface ore dumps and open cuts. Transport of this contaminant mercury to the tidal marsh appears to be influenced by hydrologic modifications in the watershed, including dam building and subsidence related to groundwater withdrawal. Although San Francisco Estuary is contaminated with mercury from numerous historic mining sources, including late 19th century hydraulic gold mining in the Sierra Nevada, there is little evidence of pre-mining contamination from natural mercury sources in the southern reach of San Francisco Estuary. Copyright 2004 Elsevier B.V. All rights reserved.

Connon, R., J. Geist, et al. (2009). "Linking mechanistic and behavioral responses to sublethal esfenvalerate exposure in the endangered delta smelt; Hypomesus transpacificus (Fam. Osmeridae)." BMC Genomics 10(1): 608.

Connon, R. E., L. Deanovic, and I. Werner (2010). Application of novel biomarkers to determine sublethal contaminant exposure and effects in delta smelt. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Connon, R. E., L. Deanovic, S. Beggel, R. Hudson-Davies, and I. Werner (2010). Molecular biomarkers in endangered species: Responses to sublethal ammonia exposure in the endangered delta smelt; Hypomesus transpacificus (Fam. Osmeridae). 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The delta smelt (Hypomesus transpacificus) is a pelagic fish species endemic to the Sacramento-San Joaquin Estuary in Northern California, listed as endangered under both the USA Federal and Californian State Endangered Species Acts and acts as an indicator of ecosystem health in its habitat range. Interrogative tools are required to successfully monitor effects of contaminants upon the delta smelt, and

to research potential causes of population decline in this species. We use molecular biomarkers to investigate genome-wide effects in fish exposed to delta water samples with a focus on locations that are impacted by contaminants, and quantitatively link expression of select biomarker genes to ecologically relevant endpoints such as the ability to swim normally. Effects of wastewater effluent toxicity were further assessed and compared to those elicited by ammonia/um alone. An ammonium transporter gene (RHCG), expressed in gills, was significantly upregulated correlating with ammonia concentrations in a dose-dependent manner, as were genes involved in neurological activity (aspartoacylcase) and muscular atrophy (atrogin-1). Furthermore, a developmental gene, expressed in vertebra (collagen XI alpha) was significantly downregulated. Results suggest a synergistic effect of ammonia with other contaminants present in wastewater treatment effluent. Evaluation of swimming performance demonstrated decreased activity and erratic behavior; effects explained by the neuromuscular responses measured using the molecular biomarkers. The results of this project will assist in identifying the sources and extent of contaminant impacts on larval delta smelt, thus guiding future management actions. Results will allow a comparison of contaminant profiles arising from agricultural and other anthropogenic activities that may directly affect delta smelt development and as such population dynamics.

Connon, R. E., L. Deanovic, S. Beggel, and I. Werner (2010). Refining tools to distinguish pyrethroid toxicity from other contaminants: a TIE approach utilizing transcriptomics. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Connon, R. E., S. Beggel, et al. (2011). "Linking molecular biomarkers with higher level condition indicators to identify effects of copper exposures on the endangered delta smelt (Hypomesus transpacificus)." Environmental Toxicology and Chemistry 30(2): 290-300.

Abstract The delta smelt (Hypomesus transpacificus) is an endangered pelagic fish species endemic to the Sacramento–San Joaquin estuary (CA, USA), and considered an indicator of ecosystem health. Copper is a contaminant of concern in Californian waterways that may affect the development and survival of this endangered species. The experimental combination of molecular biomarkers with higher level effects may allow for interpretation of responses in a functional context that can be used to predict detrimental outcomes caused by exposure. A delta smelt microarray was developed and applied to screen for candidate molecular biomarkers that may be used in monitoring programs. Functional classifications of microarray responses were used along with quantitative polymerase chain reaction determining effects upon neuromuscular, digestive, and immune responses in Cu-exposed delta smelt. Differences in sensitivity were measured between juveniles and larvae (median lethal concentration = 25.2 and 80.4 μg/L $Cu2+$, respectively). Swimming velocity declined with higher exposure concentrations in a dose-dependent manner ($r = -0.911$, $p < 0.05$), though was not statistically significant to controls. Genes encoding for aspartoacylase, hemopexin, α-actin, and calcium regulation proteins were significantly affected by exposure and were functionally interpreted with measured swimming responses. Effects on digestion were measured by upregulation of chitinase and downregulation of amylase, whereas downregulation of tumor necrosis factor indicated a probable compromised immune system. Results from this study, and many others, support the use of functionally characterized molecular biomarkers to assess effects of contaminants in field scenarios. We thus propose that to attribute environmental relevance to molecular biomarkers, research should concentrate on their application in field studies with the aim of assisting monitoring programs. Environ. Toxicol. Chem. 2011;30:290–300. © 2010 SETAC

Connon, R. E., L. A. Deanovic, et al. (2011). "Sublethal responses to ammonia exposure in the endangered delta smelt; Hypomesus transpacificus (Fam. Osmeridae)." Aquatic Toxicology 105(3-4): 369-377.

The delta smelt (Hypomesus transpacificus) is an endangered pelagic fish species endemic to the Sacramento-San Joaquin Estuary in Northern California, which acts as an indicator of ecosystem health in its habitat range. Interrogative tools are required to successfully monitor effects of contaminants upon the delta smelt, and to research potential causes of population decline in this species. We used microarray technology to investigate genome-wide effects in fish exposed to ammonia; one of multiple contaminants arising from wastewater treatment plants and agricultural runoff. A 4-day exposure of 57-day old juveniles resulted in a total ammonium (NH4+-N) median lethal concentration (LC50) of 13 mg/L, and a corresponding un-ionized ammonia (NH3) LC50 of 147 µg/L. Using the previously designed delta smelt microarray we assessed altered gene transcription in juveniles exposed to 10 mg/L NH4+-N from this 4-day exposure. Over half of the responding genes were associated with membrane integrity and function, however, neurological and muscular function was also affected. Amongst the notable pathways affected by ammonium exposure, directly associated with cellular membranes, are energy metabolism through oxidative phosphorylation, cellular responses to environmental stimuli, highlighted through signal transduction and molecular interactions, cellular processes encompassing transport and catabolism, along with cell motility, development, communication and cell death. To assess these impacts further, key genes were selected as potential biomarkers and investigated using quantitative PCR analysis on fish exposed to 2.5, 5, 10, 20 and 40 mg/L NH4+-N. Quantitative PCR results indicate biphasic responses, pivoting around the estimated no-observed effect concentration (NOEC; 5.0 mg/L NH4+-N) and below. Genes significantly affected by ammonia exposure include claudin-10, Keratin-15, Septin-3, Transmembrane protein 4, superfamily 4 (membrane), Tropomyosin, Myosin light chain, Calmodulin (muscular), Tubulin cofactor beta (neurological), Sirtuin-6 (development), and Rhesus associated type C glycoprotein 1 (gill- and skin-specific ammonium transporter). The quantitation of the ammonium transporter may highlight the capacity of delta smelt to contend with elevated levels of ammonia, the peak response of which may be indicative of short-term thresholds of tolerance. Our study supports the notion that exposure to ammonia results in cell membrane destabilization, potentially affecting membrane permeability, enhancing uptake and thus synergistic effects of multiple-contaminant exposure.

Connor, M. S., J. A. Davis, et al. (2007). "The slow recovery of San Francisco Bay from the legacy of organochlorine pesticides." Environmental Research 105(1): 87-100.

The use of organochlorine pesticides, including DDTs, chlordanes, and dieldrin, peaked in San Francisco Bay's watershed 30-40 years ago, yet residues of the pesticides remain high. Known as legacy pesticides for their persistence in the Bay decades after their uses ended, the compounds and their breakdown products occur at concentrations high enough to contribute to advisories against the consumption of sport fish from the Bay. Combined with other data sets, the long-term monitoring data collected by the San Francisco Estuary Regional Monitoring Program (RMP) for trace substances allow us to track recovery of the Bay from these inputs and predict its future improvement. Legacy pesticides enter the water and sediment of San Francisco Bay from a variety of sources, including runoff from California's Central Valley and local watersheds, municipal and industrial wastewater, atmospheric deposition, erosion of historically contaminated sediment deposits, and dredging and disposal of dredged material. Runoff from small-urbanized tributaries may contribute as much or more to the loads than runoff from the agricultural Central Valley, even though 90 percent of the freshwater flow comes from the Central Valley via the Sacramento and San Joaquin rivers. The fates of legacy pesticides in San Francisco Bay are controlled by their chemical properties, including their solubilities and partition coefficients. Degradation in the sediments, outflow through the Golden Gate, and volatilization-in that relative order-result in removal of pesticides from the Bay. A contaminant fate model was used to estimate recovery times of the Bay under various scenarios. For example, under a scenario in which no new legacy pesticides entered the Bay, model predictions suggested that concentrations of pesticides in the water and the active sediment layer would reach risk-reduction goals within one to three decades. Under scenarios of continued inputs to the Bay, recovery time would be considerably longer or not reached at all. Long-term tissue monitoring corroborates model predictions of slow declines in DDT and chlordane concentrations. Field-transplanted bivalve samples indicate declines since 1980, and lipid-weight concentrations of pesticides have declined in fishes, but the declines are slow. The critical management question for the Bay is whether there are feasible management actions that would decrease concentrations in sport fish significantly faster than the existing slow progress that has been observed.

Conomos, T. (1979). Properties and circulation of San Francisco Bay waters. San Francisco Bay: the urbanized estuary. T. Conomos. San Francisco, CA, Pacific Division of the American Association for the Advancement of Science c/o California Academy of Sciences Golden Gate Park San Francisco, California 94118: 47-84.
Differences in river and waste-water inflow and wind stress create contrasting environments and dissimilar distributions of properties between the northern and southern reaches of the San Francisco Bay system. A conceptual framework describing the physical processes which control these distributions, although still incomplete, is outlined.

The northern reach receives 90% of the mean annual river inflow and 24% of the waste-water inflow. It changes from a partially mixed estuary, with a vertical salinity gradient of 10% during high river inflow, to a well-mixed estuary with a vertical salinity gradient of 3% during low summer inflow. The southern reach also has seasonally varying water properties. There the variations are determined by water exchange from the northern reach and the ocean and by direct waste inflow (76% of total Bay waste inputs). Salinity stratification is present during winter, whereas during summer the water is nearly isohaline because of wind and tidal mixing.

Our knowledge of transport mechanisms is fragmentary. The northern reach has a permanent estuarine circulation cell that is largely maintained by the salinity-controlled density differences between river and ocean waters. Although wind variations alter this circulation, it is largely modulated by the timing and magnitude of the highly seasonal river inflow. This non-tidal circulation is nearly equivalent to tidal diffusion in controlling the water-replacement rates in the channels, which vary from weeks (winter) to months (summer). The southern reach, in contrast, has seasonally reversing but sluggish near-bottom and surface non-tidal currents that are generated by prevailing summer and episodic winter storm winds and by winter flows of Delta-derived low salinity water from the northern reach. Although the diffusion of substances by the strong tidal currents is notable, the relative importance of diffusion by strong tidal currents and the episodic advective processes in controlling water replacement mechanisms and rates has not yet been fully determined.

Studies of transport processes in San Francisco Bay, an estuary surrounded by a heavily urbanized area, could now most profitably focus on water-replacement mechanisms and rates because inflowing water dilutes unfavorable anthropogenic substances and flushes them from the system. Of greatest importance are studies defining the effects of river inflow in modulating water residence time, not only because inflow is perhaps the dominant agent in this modulation but also because man is able to control the inflow through massive river diversions.

Conomos, T. J., Ed. (1979). San Francisco Bay: The urbanized estuary. San Francisco, CA, Pacific Division, American Association for the Advancement of Science.

Conomos, T. J., R.E. Smith, and J.W. Gartner (1985). "Environmental setting of San Francisco Bay (California, USA)." Hydrobiologia 129(1): 1-12.
San Francisco Bay, the largest bay on the California coast, is a broad, shallow, turbid estuary comprising two geographically and hydrologically distinct subestuaries: the northern reach lying between the connection to the Pacific Ocean at the Golden Gate and the confluence of the Sacramento-San Joaquin River system, and the southern reach (herein called South Bay) between the Golden Gate and the southern terminus of the bay. The northern reach is a partially mixed estuary dominated by seasonally varying river inflow, and the South Bay is a tidally oscillating lagoon-type estuary. Freshwater inflows, highest during winter, generate strong estuarine circulation and largely determine water residence times. They also bring large volumes of dissolved and particulate materials to the estuary. Tidal currents, generated by mixed semidiurnal and diurnal tides, mix the water column and, together with river inflow and basin geometry, determine circulation patterns. Winds, which are strongest during summer and during winter storms, exert stress on

the bay's water surface, thereby creating large waves that resuspend sediment from the shallow bay bottom and, together with the tidal currents, contribute markedly to the transport of water masses throughout the shallow estuary.

Conomos, T. J. and D. H. Peterson (1977). Suspended-particle transport and circulation in San Francisco Bay: an overview. Estuarine Processes, Vol II. M. Wiley. New York, Academic Press. 2: 82-97.

Conomos, T. J., D. H. Peterson, et al. (1970). Movement of seabed drifters in the San Francisco Bay estuary and the adjacent Pacific Ocean: A preliminary report, US Geological Survey.

Conomos, T. J., R. E. Smith, et al. (1979). Processes affecting seasonal distributions of water properties in the San Francisco Bay estuarine system. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 115-142.
The timing and general location of major processes modifying the distributions of conservative (temperature, salinity, alkalinity) as well as biologically reactive (oxygen, carbon, nutrients, pH) water properties can be inferred from the seasonal features of the Delta-outflow hydrograph. River-modulated physical effects on these distributions in near-surface midchannel water are characteristically defined by season (high versus low river inflow) and geographic region (northern versus southern reach of the estuarine system).
Delta outflow directly controls and often dominates the spatial and temporal distributions of most properties and biological processes in the northern reach. The outflow contributes suspended particles, dissolved oxygen, and silicate, and generates an estuarine circulation cell and a turbidity maximum. The circulation pattern and associated features largely dictate spatial distributions. Seasonal changes, however, are caused by relative changes in outflow (which determine water-residence time and thus flushing rates) and light-limited biological activity (photosynthesis, nutrient uptake, and oxygen production): during winter, mixing and advection control biological activity, whereas during summer, both biological activity and physical processes are important.
The relation between Delta outflow and biological processes in the southern reach, however, is less direct: biological activity has a relatively greater effect on the spatial and temporal distributions of these properties. Distributions of properties are dominated by the perennial inflow of detritus and nutrient-rich waste water at the southern boundary. These inputs are augmented during winter by discharges from local intermittent streams that may contribute large amounts of nitrogenous compounds. The substrate is the major source of particles and dissolved silicate. Greatest biological activity apparently takes place during spring rather than summer as in the northern reach. This increased activity in the southern reach is caused in part by Delta-outflow induced stratification that tends to maintain algal cells in the photic zone.

Conrad, J. L., K.L. Smith, E. Hestir, M. Santos, A. Sih, and S. Ustin. (2009). Largemouth bass abundance and diet in the Sacramento-San Joaquin Delta: Investigating temporal and spatial variation with respect to submerged aquatic vegetation. Strate of the Estuary Conference. Oakland, CA.

Conrad, J. L., K.L. Weinersmith, M.J. Young, D.P. De Carion, E.L. Hestir, M.J. Santos, P. Crain, S.L. Ustin, P.B. Moyle, and A. Sih (2010). More big bass: Understanding the role of largemouth bass as top predators in the littoral zone. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
While numerous pelagic organisms in the Sacramento-San Joaquin Delta have declined precipitously in recent years, abundance of non-native centrarchids in the littoral zone has increased substantially. Sharp inclines in the largemouth bass (LMB) populations, with an apparent particular increase in large, piscivorous LMB,

are of special interest due to the potential for direct impacts on native fishes via predation. The aims of this study were to address potential reasons for the population increase in LMB by determining abiotic and biotic factors influencing LMB distribution and abundance in the Delta, and to assess the diet composition of LMB across seasons. Previous studies have hypothesized that LMB and other non-native fishes have benefited from an expansion of submerged aquatic vegetation (SAV) in the Delta; thus, a specific goal was to quantify the relationship between SAV and prominent resident fishes in the littoral zone, particularly LMB. To address these questions, we have conducted bimonthly boat electrofishing surveys and characterized SAV species composition and biomass at 33 locations throughout the Delta since October of 2008. Results indicate that SAV favors recruitment success of juveniles for many resident fishes, including LMB, likely by promoting secondary productivity in SAV beds that in turn supports the diets of juvenile fishes. Adult LMB diet is composed primarily of vegetation-associated prey (e.g. sunfish and crayfish) throughout the year, suggesting that foraging excursions into pelagic areas are rare. Instead, SAV may promote the abundance of key diet items for adult LMB, thus facilitating an increase in the numbers of large LMB. This study provides new insight into how SAV may provide a mechanism for population increases for many littoral, non-native fishes. In addition, quantification of LMB and other species' responses to SAV biomass provides important information to managers interested in modeling how control of SAV may influence resident fish abundance.

Conrad, J. L.,
K. L. Weinersmith, M. J. Young, D. de Carion, P. Crain, D. J. Harris, M.C. Ferrari, E.L. Hestir, M.J. Santos, S.L. Ustin, P. B. Moyle, and A. Sih (2010).
Rising abundance of largemouth bass in the littoral zone of Sacramento –San Joaquin Delta: the role of Egeria densa. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Conrad, J. L., E.A. Gilbert-Horvath, and J.C. Garza (2013). "Genetic and phenotypic effects on reproductive outcomes for captively-reared coho salmon, Oncorhynchus mykiss." Aquaculture 404-405: 10.

Captive breeding programs are a common approach to preventing extinction and rehabilitating endangered stocks of Pacific salmonids. To minimize inbreeding in these typically small populations, genetic data from microsatellite loci have been used to estimate relatedness and choose spawning pairs. Phenotypic attributes (e.g., body size), that result at least in part from environmental conditions during rearing likely affect reproductive outcome as well. However, the combined effects of individual phenotype and genetic broodstock management have not been previously evaluated. This study assessed the influence of genetic background (source of original broodstock collection, and heterozygosity of both male and female parents), the molecular genetic-derived relatedness coefficient of mated pairs, and phenotypic attributes of female parents (body size, ovulation rate) on reproductive outcome for three brood years of endangered coho salmon, Oncorhynchus kisutch, from the Russian River, California. Over 1200 full-sibling family groups were created in total, whose survival was tracked individually from fertilization through the swim-up fry stage. Strong maternal influence on reproductive outcome was found, as increased female body mass resulted in lower progeny survival rates, and higher ovulation rates predicted improved progeny survival. Male and female heterozygosity was generally positively related to embryo survival, but this effect was not consistently observed across brood years or early life stages. The relatedness coefficient between mated pairs had a significant and negative effect on progeny survival, particularly after hatching, even though the most inbred matings were prevented. Thus, use of genetic broodstock management to guide selection of salmon breeding pairs increases offspring survival, in addition to reducing inbreeding.

Conrad, J. L. a. A. S. (2009). "Behavioral type in newly emerged steelhead fry (Oncorhynchus mykiss) does not predict fitness in a conventional hatchery rearing environment." Journal of Fish Biology 75: 17.

Behavioural assays were conducted on newly emerged steelhead Oncorhynchus mykiss to investigate
the presence of behavioural syndromes and to determine whether behavioural type in young fish

predicts growth rate in a conventional hatchery rearing environment. Individual fry were consistent
in their position choice and activity behaviours across safe and unsafe contexts, as well as among
assays conducted on different days. Position choice and activity behaviours, however, were not
necessarily correlated to each other. Both behaviours predicted feeding rates during behavioural
assays, but there was no relationship between fry behaviour and subsequent growth rate or survival
during the first 3 months of hatchery rearing. These results support the hypothesis that selection
in captivity may be relaxed with respect to behavioural type rather than directional, allowing for
increased behavioural variance in domesticated populations. Modest magnitudes of correlations
among fry behaviours, however, suggest that behavioural type may be unstable at the onset of the
juvenile feeding stage.

Contreras, D., J. Messineo, S. Slater, and R. Baxter (2010). Behind the Science: The underwater story of the Midwater Trawl. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Cook, L. and L. D. Buffaloe (1998). Delta agricultural diversion evaluation summary report, 1993-1995. Sacramento CA, Interagency Ecological Program for the San Francisco Bay/Delta Estuary.

Cooper, R. C. and C. A. Keller (1969). Epizootiology of papillomas in English sole, Parophrys vetulus. Neoplasms and related disorders of invertebrate and lower vertebrate animals. C. J. Dawe and J. C. Harshbarger. Washington, Smithsonian Institution: 173-185.

Cordell, J. R., S. M. Bollens, et al. (2008). "Asian copepods on the move: recent invasions in the Columbia-Snake River system, USA." ICES Journal of Marine Science 65: 753-758.
Cordell, J. R., Bollens, S. M., Draheim, R., and Sytsma, M. 2008. Asian copepods on the move: recent invasions in the Columbia-Snake River system, USA. - ICES Journal of Marine Science, 65: 000-000. Nine Asian copepod species have been introduced into the Northeast Pacific, seven of which are largely confined to the San Francisco estuary. However, several of these copepods recently invaded the Columbia-Snake River system in Washington state, USA. In addition to the calanoid copepod Pseudodiaptomus inopinus, which appeared in the 1980s, the Columbia River now has populations of the calanoids Pseudodiaptomus forbesi and Sinocalanus doerrii, and the cyclopoid copepod Limnoithona tetraspina. Sampling in the Columbia-Snake River system in 2005 and 2006 indicated that (i) newer invaders may have displaced the previously introduced P. inopinus; (ii) P. forbesi had moved upstream into the first five reservoirs in the system; (iii) the other species occurred only in the tidal regions of the lower river; (iv) P. forbesi dominates the late summer holoplankton in the lower river and estuary; and (v) P. forbesi is relatively rare, and the holoplankton is dominated by native species in upstream free-flowing segments of the Columbia River and in reservoirs of the Snake River. Zooplankton samples from ships in Puget Sound suggest that ballast water from California is a major source of the introduced copepods and that the Columbia River itself may be a new source of ballast-introduced copepods.

Courter, I., M. Teply, S. Cramer, B. Cavallo, and J. Merz (2010). Quantifying flow and temperature effects on production of Central Valley steelhead. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Central Valley steelhead are an ESA listed species playing an increasingly pivotal role in reservoir and Delta water management. The influence of resident rainbow trout on production of anadromous steelhead has been repeatedly identified

as a critical uncertainty during evaluations of threatened and endangered steelhead (Oncorhynchus mykiss) populations. The freshwater resident form of O. mykiss (rainbow trout) is not currently listed under the ESA, but two expert panels of independent scientists have concluded that population viability analyses for O. mykiss should account for the interdependence of both the resident and anadromous forms where they coexist. Given the importance of Central Valley O. mykiss to water project management and deliveries, and pervasive misconceptions about the interplay between resident and anadromous rainbow trout, we propose to use successful programs originally developed in Washington (seehttp://www.fishsciences.net/projects/yakima/) as a steppingstone for development of a steelhead modeling framework for the California Central Valley. Modeling conducted in watersheds in Washington and Oregon indicate that flow and temperature conditions may strongly influence predominance of resident or anadromous life-histories, suggesting that trends in abundance of resident rainbow trout and steelhead can be predicted under a variety of flow management regimes. Furthermore, production of steelhead in regulated river systems was shown to be inextricably linked to abundance of resident rainbow trout, and anadromous juvenile production from resident spawners appears to be an important driver of steelhead persistence during periods of low marine survival.

Cowan, K., S. Fong, B. Templin, and A. Webber-Stover (2013). California Estury Monitoring Workgroup: Using Web Portals to Improve Scientific Understanding. Interagency Ecological Program Annual Workshop - 2013. Lake Natoma Inn, Folsom, CA.

Getting to “One Delta One Science” in Sacramento San Joaquin estuary will require an integration of science with policy and management action not only at the local level, but at regional and
state levels as well. Estuary biology and ecology, along with social, political and economic considerations, can influence policy design and implementation. Decision-support tools can integrate
these sciences and facilitate discussion by organizing and simplifying often complex processes into a format that the public, policy makers and managers can understand, use and amend.
The California Estuary Monitoring Workgroup (CEMW) is beginning to answer stakeholder questions with a collaborative toolset that brings together peer-reviewed datasets with useful tools to help practitioners
tell their stories. This presentation will describe the workgroup's collaborative approach as a workgroup of the CA Water Quality Monitoring Council. The presentation will also demonstrate the current toolset
and ongoing efforts.

Statement of Relevance: Decision-support tools can integrate sciences and facilitate discussion by organizing and simplifying often complex processes into a format that the public, policy makers and
managers can understand, use and amend.

Crain, P. K., K. Whitener, et al. (2004). Use of a Restored Central California Floodplain by Larvae of Native and Alien Fishes. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 125-140.

We sampled larval fish in 1999 and 2001 on a restored floodplain along the lower Cosumnes River, California, from the onset of flooding to when the sites dried or when larval fish became rare. We collected more than 13,000 fish, of which prickly sculpin Cottus asper made up the majority (73%). Eleven species made up 99% of the catch. Three native fishes (prickly sculpin, Sacramento sucker Catostomus occidentalis, and splittail Pogonichthys macrolepidotus) and two alien species (common carp Cyprinus carpio and bigscale logperch Percina macrolepida) were associated with higher inundation and cool temperatures of early spring. In contrast, five alien taxa, sunfish Lepomis spp., largemouth bass Micropterus salmoides, crappie Pomoxis spp., golden shiner Notemigonus crysoleucas, and inland silverside Menidia beryllina, were associated with less inundation and warmer water temperatures. One native species, Sacramento blackfish Orthodon microlepidotus, was also associated with these conditions. Species did not show strong associations with habitat because of different spawning times of adults and expansion and contraction of flood waters. Most species could be found at all sites throughout flooded habitat, although river and floodplain spawning fishes usually dominated sites closest to levee breaches. Highest species richness was consistently found in two sloughs with permanent water because they both received drainage water from the floodplain and had a complement of resident species. Splittail, a floodplain spawner, was found primarily in association with submerged annual plants. Our results suggest that a natural hydrologic cycle in spring is important for providing flooding and cool temperatures important for many native larval fishes. Alien fishes are favored if low flows and higher temperatures prevail. Restoration of native fish populations that use floodplains for rearing should emphasize early (February-April) flooding followed by rapid draining to prevent alien fishes from becoming abundant.

Cramer, S. (2010). Translating fish salvage at the Delta pumps into abundance of chinook salmon smolts. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Fish salvage data at the state and federal pumps in the Delta represent a long time series of sampling that has been variously used to index the timing, abundance, and mortality of juvenile Chinook passing through the Delta. Interpretation of the salvage data has been confounded by large fluctuation in the rates of pumping and by uncertainty in the proportion of smolts that pass through Delta routes proximal to the pumps. I used smolt sampling data from other stations in the Delta to establish the temporal correlations of fish density, hatchery origin, size, and genotype to those of fish salvaged at the pumps. I found comparisons among stations to be useful for discriminating which independent sampling provided a meaningful index of fish density in the Delta for fish of similar size and origin to those salvaged at the pumps. The abundance index accounted for much of the variability in salvage at the pumps, and also made it possible to estimate the fraction of change in salvage that could be associated with each of two factors related to pumping rate: (1) the proportion of local water volume sieved at the salvage facilities, and (2) the additional proportion of fish drawn into the pump vicinity in response to flow drawn to the pumps.

Cramer, S. P. and D. B. Demko (1997). "The status of late-fall and spring chinook salmon in the Sacramento River basin regarding the Endangered Species Act."

Cranston, P. S., G.M. Benigno, and M.C. Domingeuz (2007). Hydrobaenus saetheri Cranston, new species, an aestivating, winter-emerging chironomid (Diptera: Chironomidae) from California. Contributions to the systematics and ecology of aquatic diptera: A tribute to Ole A Saether T. Andersen, The Caddis Press: 73-79.
A new orthocladiine midge, Hydrobaenus saetheri Cranston, new species, is described from larvae, pupae and adults, evidently belonging to the genus Hydrobaenus Fries. Larvae aestivate over summer, and commence development as soon as wetted when winter-rains induce flow in seasonal waterways. Larvae of this species dominate in the early flow, and adult numbers can reach nuisance levels in mid-winter.

Crimaldi, J. P., J. K. Thompson, et al. (2002). "Hydrodynamics of larval settlement: The influence of turbulent stress events at potential recruitment sites." Limnology and Oceanography 47: 1137-1151.
We describe a laboratory investigation into the effect of turbulent hydrodynamic stresses on clam larvae in the settlement phase of the recruitment process. A two-component laser-Doppler anemometer (LDA) was used to measure time histories of the instantaneous turbulence structure at potential recruitment sites within reconstructed beds of the adult Asian clam, Potamocorbula amurensis. Measurements were made for two flow speeds over beds with three different clam densities and two different clam heights. We analyze the statistical effect of the turbulence on the larval flux to the bed and on the probability of successful anchoring to the substrate. It is shown that the anchoring probability depends on the nature of the instantaneous stress events rather than on mean stresses. The instantaneous turbulence structure near the bed is altered by the flow rate and the spacing and height of adult clams living in the substrate. The ability to anchor quickly is therefore extremely important, since the time sequence of episodic turbulent stress events influences larval settlement success. The probability of successful larval settlement is predicted to decrease as the spacing between adults

decreases, implying that the hydrodynamics impose negative feedback on clam bed aggregation dynamics.

Croteau, M. N. and S. N. Luoma (2005). "Delineating copper accumulation pathways for the freshwater bivalve Corbicula using stable copper isotopes." Environmental Toxicology and Chemistry 24(11): 2871-2878.
Delineation of metal uptake routes in aquatic invertebrates is critical for characterizing bioaccumulation dynamics and assessing risks associated with metal exposure. Here we demonstrate that Cu stable isotopic ratios can be manipulated in both exposure media and algae to determine the efflux rate constant (k sub(e)) and to estimate Cu assimilation efficiency (AE) from ingested food in a freshwater bivalve (Corbicula fluminea). The Cu AE in Corbicula fed super(65)Cu-spiked Cryptomonas ozolini was 38%. Copper uptake routes had no significant influence on efflux; k sub(e) of 0.004 per day characterized the slowest component of efflux following short-term exposures to super(65)Cu in water or in both food and water. Incorporation of the physiological parameters for dietary and dissolved uptake as well as rate constants of loss into a bioaccumulation model allowed for assessing the relative contribution of water and food as Cu sources. At [super(65)Cu super(2+)] of 6.7 mu g/L, Corbicula accumulated twice as much Cu from diet as from water. In most freshwater systems, the dietary pathway is likely to act as the major Cu uptake route for Corbicula. Extrapolation of our laboratory results to the San Francisco Bay-Delta (California, USA) indicated that our biodynamic model and the laboratory-derived parameters for dietary super(65)Cu uptake provided a realistic representation of the processes involved in Cu accumulation by the bivalve Corbicula.

Croteau, M.-N., S. N. Luoma, et al. (2005). "Trophic transfer of metals along freshwater food webs: Evidence of cadmium biomagnification in nature." Limnology and Oceanography 50(5): 1511-1519.
We conducted a study with cadmium (Cd) and copper (Cu) in the delta of San Francisco Bay, using nitrogen and carbon stable isotopes to identify trophic position and food web structure. Cadmium is progressively enriched among trophic levels in discrete epiphyte-based food webs composed of macrophyte-dwelling invertebrates (the first link being epiphytic algae) and fishes (the first link being gobies). Cadmium concentrations were biomagnified 15 times within the scope of two trophic links in both food webs. Trophic enrichment in invertebrates was twice that of fishes. No tendency toward trophic-level enrichment was observed for Cu, regardless of whether organisms were sorted by food web or treated on a taxonomic basis within discrete food webs. The greatest toxic effects of Cd are likely to occur with increasing trophic positions, where animals are ingesting Cd-rich prey (or food). In Franks Tract this occurs within discrete food chains composed of macrophyte-dwelling invertebrates or fishes inhabiting submerged aquatic vegetation. Unraveling ecosystem complexity is necessary before species most exposed and at risk can be identified.

Culberson, S. D. (2001). The interaction of physical and biological determinants producing vegetation zonation in tidal marshes of the San Francisco Bay Estuary, California, USA, University of California, Davis: 142.

Culberson, S. D., C.B. Harrison, C. Enright, and M.L. Nobriga (2004). Sensitivity of larval fish transport to location, timing, and behavior using a particle tracking model in Suisun Marsh, California. Early life history of fishes in the San Francisco Estuary and watershed. F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi. Bethesda, Maryland, American Fisheries Society. Symposium 39: 257-267.
We used a coupled hydrodynamic-particle tracking model to assess the relative importance of factors affecting transport and entrainment risk for generalized fish larvae in Suisun Marsh in the San Francisco Estuary, California. Factors examined included location of particle release, time of particle release, vertical migration behavior, and combinations thereof. Model sensitivity was evaluated by observing particle entrainment into a water diversion in Suisun Marsh under various scenarios and compared to randomized input cases. Scenarios combining two or more factors indicated nonlinear interactions, including evidence of tidal pumping on neap tides near our test diversion. Our study suggests that accurate

modeling of larval transport depends on accurate determination of fish locations, tidal and residual time scale circulation simulation, and fish behavior during early life stages. We also examined appropriate approaches to modeling these factors

Culberson, S. D., T. C. Foin, et al. (2004). "The role of sedimentation in estuarine marsh development within the San Francisco Estuary, California, USA." Journal of Coastal Research 20(4): 970-979.
FRIEDRICHs and PERRY (2001) have hypothesized that exogenous sedimentation is a vital part of a feedback system (with tidal height, marsh elevation and local vegetation) that keeps the marsh surface in equilibrium with sea level. This study investigated the relationship between local sedimentation rates, presence of overlying vegetation, distance from tidal channel, and local elevation in two marshes located in the San Francisco Estuary. Exogenous sedimentation rates measured using sediment traps on marsh plains at approximately MHW were found to be much lower than expected. Sedimentation rates were highest closest to tidal channels, regardless of overlying vegetation, but declined rapidly on the inland portions of the marsh and were never high enough to build the marsh plain at rates greater than 0.91-1.37 mm m(-2) yr(-1). Maintenance of tidal marsh elevations solely by exogenous sedimentation within the San Francisco Estuary seems unlikely. Observations that local marshes keep pace with sea level rise implicate local productivity as the source of increased sediments.

Currie, R. J., W.A. Bennett, and T.L. Beitinger (1998). "Critical thermal minima and maxima of three freshwater game-fish species acclimated to constant temperatures." Environmental Biology of Fishes 51(2): 187-200.
A total of 120 critical thermal maxima (CT maxima) and 120 critical thermal minima (CT minima) were determined for channel catfish, largemouth bass and rainbow trout acclimated to three constant temperatures: 20, 25 and 30 °C in catfish and bass, and 10, 15 and 20 °C in trout. Highest mean CT maximum and lowest mean CT minimum measured over these acclimation temperatures were 40.3 and 2.7 °C (catfish), 38.5 and 3.2 °C (bass) and 29.8 and 0.0 °C (trout). Temperature tolerance data were precise with standard deviations generally less than 0.5 °C. Channel catfish had the largest thermal tolerance scope of the three species while rainbow trout had the lowest tolerance of high temperatures and the highest tolerance of low temperatures. In all species CT minima and CT maxima were highly significantly linearly related to acclimation temperature. Within each species, slopes relating CT maxima to acclimation temperature were approximately half as large as those relating CT minima to acclimation temperature, suggesting that acclimation temperature has a greater influence on tolerance to low rather than high temperatures. Slopes relating both CT minima and CT maxima to acclimation temperature for the two warm-water species were similar and approximately twice those for the rainbow trout.

Cutter, G. (1988). Selenium Behavior in the Sacramento-San Joaquin Estuary, California. , IESP (Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary)

Cutter, G. A. (1989). "The estuarine behavior of selenium in San Francisco Bay " Estuarine, Coastal and Shelf Science 28(1): 13-34.
In April and September 1986 concentrations of dissolved selenate, selenite and Se(−II+O), suspended particulate selenium, nutrients, chlorophyll a and total suspended matter, were determined in the San Francisco Bay estuarine system. In addition, dissolved selenium speciation was determined in the Sacramento and San Joaquin Rivers between 1984 and 1987. The April 1986 estuarine sampling occurred during high river discharge, and within the Northern Reach of San Francisco Bay mid-estuarine input of selenite and Se(−II+O) is apparent, while selenate appears to be removed. During September 1986 river discharge rates were approximately four orders of magnitude lower than in April, and the mid-estuarine production of all selenium species is apparent. In contrast, dissolved selenium in the South San Francisco Bay generally shows conservative mixing behaviour during April and September 1986. The source of dissolved selenium in the South Bay appears to be effluents from sewage treatment plants. In the Northern Reach effluents from oil refineries located in the mid-estuary may be major sources of selenium input during

low river discharge periods. However, during periods of high river discharge the sources and sinks of dissolved selenium species within the Northern Reach remain unidentified.

Cutter, G. A. and L. S. Cutter (2004). "Selenium biogeochemistry in the San Francisco Bay estuary: changes in water column behavior." Estuarine, Coastal and Shelf Science 61(3): 463-476.

The cycling of dissolved selenium was examined in the North San Francisco Bay estuary using 5 surface water transects from the Pacific Ocean (Golden Gate) to the Sacramento and San Joaquin Rivers, monthly river sampling, and three collections of oil refinery effluents during 1997-2000. By combining these data with earlier results from the mid-1980s, a nearly 16-year record of riverine fluxes, estuarine processes, and anthropogenic inputs was obtained. The Sacramento River concentrations and speciation have remained unchanged over the period, and while the speciation of selenium in the San Joaquin is similar, its dissolved selenium concentrations have decreased by almost one half. More significantly, the concentration of selenium from oil refinery discharges to the mid-estuary has decreased 66% and its speciation changed from one dominated by selenite (66%) to one that is only 14% selenite. This change in refinery effluents occurred while our study was underway, with the result being a pronounced decrease in selenite concentrations (82%), and hence total dissolved selenium, in the mid-estuary. A companion study found that sediment/ water exchange is a minor flux to the estuary, and hence selenium inputs from the Sacramento River, as well as refineries during low flow (summer, fall) periods exert major controls on the dissolved selenium behavior in this estuary. Nevertheless, in situ processes associated with organic matter cycling (photosynthesis and respiration) still modify the distributions and internal transformations of dissolved selenium, notably organic selenide. Copyright 2004 Elsevier Ltd. All rights reserved.

Cutter, G. A. and M. L. C. San Diego-McGlone (1990). "Temporal variability of selenium fluxes in San Francisco Bay." The Science of the Total Environment 97/98: 235-250.

Czerniejewski, P., W. Wawrzyniak, et al. (2007). "A comparative analysis of two allochthonous populations of the Chinese mitten crab (Eriocheir sinensis H. Milne-Edwards 1853) from the Szczecin Lagoon (NW Poland) and San Francisco Bay (US West coast)." Oceanologia 49(3): 353-367.

Selected biological and morphometric characters of two populations of the non-indigenous Chinese mitten crab (Eriocheir sinensis), one from the Szczecin Lagoon (SL, Poland) and the other from San Francisco Bay (SFB,USA), both sampled in autumn, were analysed during Polish investigations. The SL crabs showed a significantly higher individual weight, length and carapace width. Males accounted for 55% (87 individuals) of the 179 SL crabs, and 62.9% (90 individuals) of the SFB crabs. Statistical analysis of metric characters, expressed as a percentage of carapace width enabled four diagnostic characters to be identified: abdomen width (X sub(2)), carapace height (X sub(3)), left claw length (X sub(7) and carapace length (X sub(1)). These jointly explain 71.75% of the differences between the SL and SFB crabs and are indicative of the distinctness of the populations.

Daehler, C. C. (1999). "Inbreeding depression in smooth cordgrass (Spartina alterniflora, Poaceae) invading San Francisco Bay." American Journal of Botany 86(1): 131-139.

The magnitude of inbreeding depression in invading plant populations is often presumed to be small and of little consequence. The purpose of this study was to assess the magnitude of inbreeding depression in a pollen-limited, partially self-incompatible, invading plant population. The magnitude and timing of inbreeding depression were compared among ten maternal plants sampled from a population of smooth cordgrass (Spartina alterniflora) invading San Francisco Bay. Selfed and outcrossed progeny were compared for embryo abortion, survival of seedlings, and growth/survival at the end of the first growing season in three greenhouse environments. Estimates of inbreeding depression varied among environments, with competitive environment > high-nutrient environment > low-nutrient environment. Population-level estimates of inbreeding depression ranged from 0.61 to 0.81;

however, maternal plants varied significantly in their magnitude of inbreeding depression, ranging from 0.1 to 0.97. The 95% confidence interval for inbreeding depression for some maternal plants included zero. There was a significant negative correlation between the overall magnitude of inbreeding depression and self-fertility rate among maternal plants. The few maternal plants with high self-fertility carried relatively little genetic load, and their selfed progeny are likely to survive on open mudflats. The noncompetitive, pollen-limited growing conditions associated with invasion may allow self-fertility to spread in this population.

Daehler, C. C., C. K. Anttila, et al. (1999). "Evolution of a new ecotype of Spartina alterniflora (Poaceae) in San Francisco Bay, California, USA." American Journal of Botany 86(4): 543-546.
The authors report the discovery and spread of a distinctly dwarf ecotype of introduced smooth cordgrass in San Francisco Bay. This dwarf ecotype has evolved since the introduction of "S. alterniflora" to San Francisco Bay from Maryland in the 1970s. The new ecotype differs ecologically from typical or 'wild-type' "S. alterniflora" and also differs significantly from the previously reported 'short-form' "S. alterniflora".

Daehler, C. C. and D. R. Strong (1995). "Impact of high herbivore densities on introduced smooth cordgrass, Spartina alterniflora, invading San Francisco Bay, California." Estuaries 18(2): 409-417.
Spartina alterniflora, smooth cordgrass, invading San Francisco Bay, California (USA), is attacked by high densities of a plant hopper, Prokelisia marginata, and a mirid bug, Trigonotylus uhleri. Both herbivores are sap-feeders. We investigated the impact of these herbivores on S. alterniflora's growth rate, vegetative spread, and seed production by manipulating herbivore densities in the field and in a greenhouse. Herbivore densities in the field peaked in early fall, with P. marginata averaging more than 300 individuals per mature culm of S. alterniflora (about 100,000 per m super(2)) and T. uhleri densities exceeding 10 per culm (about 3,000 per m super(2)). Field reductions of herbivore densities by approximately 70% with insecticidal soap did not result in greater vegetative growth rates or lateral spread of plants; plants grew vigorously with the highest densities of insects. In the greenhouse study, conducted with seedlings, herbivory significantly reduced plant mass and tiller number in some but not all replicate herbivory treatments. In both field and greenhouse, there were significant differences between some clones' growth rates independent of herbivory. Inflorescence production in the field was not affected by reduced-herbivory treatments. Seed set was low under conditions of both natural and reduced herbivory, averaging 0.4%. Despite densities of P. marginata and T. uhleri that are much higher than typically observed in areas where S. alterniflora is native, herbivory by these particular insects appears to have little impact and in unlikely to limit S. alterniflora's spread through San Francisco Bay.

Dame, R. F. and T. C. Prins (1998). "Bivalve carrying capacity in coastal ecosystems." Aquatic Ecology 31(4): 409-421.
The carrying capacity of suspension feeding bivalves in 11 coastal and estuarine ecosystems is examined. Bivalve carrying capacity is defined in terms of water mass residence time, primary production time and bivalve clearance time. Turnover times for the 11 ecosystems are compared both two and three dimensionally. Fast systems, e.g., Sylt and North Inlet, have turnover times of days or less, while, slow systems, e.g., Delaware Bay, have turnover times of months and years. Some systems, Marennes-Oleron, South San Francisco Bay and North Inlet, require a net influx of phytoplankton in order to support their bivalve populations. Three systems, Carlingford Lough, Chesapeake Bay and Delaware Bay, have very long bivalve clearance times due to small or reduced bivalve filter feeder populations. Carlingford Lough stands out because it is a naturally planktonic system now being converted to bivalve culture with an adherently stronger benthic-pelagic coupling. Existing models of bivalve carrying capacity are reviewed. The Herman model is utilized as an appropriate ecosystem level model to examine carrying capacity because it includes the three major turnover time elements of water mass residence time, primary production time and bivalve filter feeder clearance time. The

graphical analysis suggests that massive and successful bivalve filter feeder populations are found in systems with relatively short residence times (<40 days) and short primary production times (<4 days) in order to sustain a high bivalve biomass with its associated rapid clearance times. Outlier systems are constrained by long water mass residence times, extended primary production times, and long clearance times.

Daniels, R. A., and P.B. Moyle. (1983). "Life history of the splittail (Cyprinidae: Pogonichthys macrolepidotus) in the Sacramento-San Joaquin estuary." U.S. National Marine Fishery Bulletin 81: 647-654.

The Sacramento-San Joaquin estuary is the largest on the west coast of North America. Because of its comparatively young geologic age, <8,000 yr (Atwater 1979), its fish fauna is a mixture of native freshwater and marine species, to which numerous exotic species have been added in the past 100 yr (Moyle 1976). The ranges of two extant species, the delta smelt, Hypomesus transpacificus, and the split· tail, Pogonichthys macrolepidotus, are restricted to the estuary. Both species are abundant but their biology is nevertheless poorly known, since most fisheries research in the estuary has concentrated on species ofmajor economic importance, especially the introduced striped bass, Morone saxatilis (Stevens 1980; Collins 1982).

The fish communities of the estuary are changing, however, as new species are introduced and as con· ditions change in response to upstream water projects, water diversions, such as increased use of the water for cooling power plants, and pollution. Given the restricted ranges and habitats of these two species (Moyle 1976), their abundance could decline rapidly if environmental conditions become unfavorable for them, possibly making them candidates for listing as threatened species. This paper is concerned with the life history ofthe splittail, a species of interest for reasons besides its status as a potentially threatened endemic: 1) It is consistently one of the most abundant species in many of the brackish sloughs of the estuary (Moyle and Daniels unpub1. data; Caywood 1974), 2) most other cyprinids are exclusively freshwater species, rarely found in brackish waters, 3) its life history patterns reflect adaptation to an environment in which drought and flood occur episodically, and 4) it supports a small but locally important hook-and-line 'fishery (Caywood 1974).

Das, T., M.D. Dettinger, and D.R. Cayan (2010). Potential responses of Sierra Nevada flood frequencies to climate change. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

California’s rugged topography, proximity to occasional heavy moisture-laden storm systems, and a variety of human development and infrastructure in low lying areas make it highly vulnerable to floods. An important question facing the state—in terms of both protecting the public and formulating water-supply management responses to climate change—is “how might future climate changes impact flood risk in California?” To begin addressing this question, we simulated floods under a range of climate-change scenarios in the western Sierra Nevada. The investigation is based upon downscaled daily precipitation and temperature projections from three General Circulation Models (GCMs), fed through the Variable Infiltration Capacity (VIC) hydrologic model. Daily VIC-simulated streamflows, from historical and from projected climate change runs, were evaluated for possible changes in annual maximum

3-day flood magnitudes and frequencies of floods greater than selected historical thresholds. By the end of the 21st Century, all of the projections yield larger floods, for both the Northern Sierra Nevada (NSN) and for the Southern Sierra Nevada (SSN). The increases in flood magnitudes (with 50-years return intervals) are statistically significant (at p <= 0.01) for all the three GCMs in the period 2051-2099. These increases appear to derive several different climatic influences in the projections, ranging from increases in large-storm sizes, storm frequencies, and days with more precipitation falling as rain and less as snow. Increases in antecedent winter soil moisture also play a role in some areas. Thus, several mechanisms typically contribute to the projections of increased flood hazards. As a consequence of the multiple contributions to the simulated flood responses, full hydrologic modeling are likely to be required to make even general predictions, in contrast to some simpler rules of thumb of the sort that might apply to some other hydrologic responses. The problem of changing flood frequencies is complicated by the fact that responses differ from basin to basin depending on topography. This means that projections of flood changes with climate change will also be basin dependent.

Davis, J. A., A. J. Gunther, et al. (1992). "Priority pollutant loads from effluent discharges to the San Francisco Estuary." Water Environment Research 64(2): 134-140.
Effluent monitoring data collected under the National Pollutant Discharge Elimination System (NPDES) Program were used to estimate pollutant loads from effluent discharges to the San Francisco Estuary for the period of 1984-1987. Most analyses of priority pollutant concentrations in effluents yielded "below detection limit" (BDL) results. Although many pollutants were monitored in effluents, quantitative assessment of spatial and temporal trends in loads could only be performed for four pollutants (chromium, copper, nickel, and zinc) that were detected in more than 50% of analyses. Four municipal wastewater treatment facilities accounted for approximately 50% of the total loads of these elements to the Estuary. Statistically significant declines in loads from some of the largest dischargers were observed. Modifications to procedures for collecting and reporting effluent monitoring data that would enhance the value of these data in assessments of mass loading include the use of more sensitive analytical methods for pollutants of greatest concern, increased sampling frequency for large discharges, routine reporting of BDL results in their uncensored form, and comprehensive reporting of quality assurance data.

Davis, J. A., F. Hetzel, et al. (2007). "Polychlorinated biphenyls (PCBs) in San Francisco Bay." Environmental Research 105(1): 67-86.
San Francisco Bay is facing a legacy of polychlorinated biphenyls (PCBs) spread widely across the land surface of the watershed, mixed deep into the sediment of the Bay, and contaminating the Bay food web to a degree that poses health risks to humans and wildlife. In response to this persistent problem, water quality managers are establishing a PCB total maximum daily load (TMDL) and implementation plan to accelerate the recovery of the Bay from decades of PCB contamination. This article provides a review of progress made over the past 15 years in managing PCBs and understanding their sources, pathways, fate, and effects in the Bay, and highlights remaining information needs that should be addressed in the next 10 years. The phaseout of PCBs during the 1970s and the 1979 federal ban on sale and production led to gradual declines from the 1970s to the present. However, 25 years after the ban, PCB concentrations in some Bay sport fish today are still more than ten times higher than the threshold of concern for human health. Without further management action it appears that the general recovery of the Bay from PCB contamination will take many more decades. PCB concentrations in sport fish were, along with mercury, a primary cause of a consumption advisory for the Bay and the consequent classification of the Bay as an impaired water body. Several sources of information indicate that PCB concentrations in the Bay may also be high enough to adversely affect wildlife, including rare and endangered species. The greater than 90% reduction in food web contamination needed to meet the targets for protection of human health would likely also generally eliminate risks to wildlife. PCB contamination in the Bay is primarily associated with industrial areas along the shoreline and in local watersheds. Strong spatial gradients in PCB concentrations persist decades after the release of these chemicals to Bay Area waterways. Through

the TMDL process, attention is being more sharply focused on the PCB sources that are controllable and contributing most to PCB impairment in the Bay. Urban runoff from local watersheds is a particularly significant pathway for PCB entry into the Bay. Significant loads also enter the Bay through Delta outflow (riverine input). Recent studies have shown that erosion of buried sediment is occurring in large regions of the Bay, posing a significant problem with respect to recovery of the Bay from PCB contamination because the sediments being eroded and remobilized are from relatively contaminated buried sediment deposits. In-Bay contaminated sites are likely also a major contributor of PCBs to the Bay food web. Dredged material disposal, wastewater effluent, and atmospheric deposition are relatively minor pathways for PCB loading to the Bay. Priority information needs at present relate to understanding the sources, magnitude of loads, and effectiveness of management options for urban runoff; the regional influence of in-Bay contaminated sites; remobilization of PCBs from buried sediment; historic and present trends; in situ degradation rates of PCBs; reliable recovery forecasts under different management scenarios; the spatial distribution of PCBs in soils and sediments; and the biological effects of PCBs in interaction with other stressors. The slow release of pollutants from the watershed and the slow response of the Bay to changes in inputs combine to make this ecosystem very slow to recover from pollution of the watershed. The history of PCB contamination in the Bay underscores the importance of preventing persistent, particle-associated pollutants from entering this sensitive ecosystem.

Davis, J. A., D. Yee, et al. (2003). "Potential for increased mercury accumulation in the estuary food web." San Francisco Estuary and Watershed Science 1: 4.

Abstract Abstract Present concentrations of mercury in large portions of San Francisco Bay (Bay), the Sacramento-San Joaquin Delta (Delta), and the Sacramento and San Joaquin rivers are high enough to warrant concern for the health of humans and wildlife. Large scale tidal wetland restoration is currently under consideration as a means of increasing populations of sh species of concern. Tidal wetland restoration activities may lead to increased concentrations of mercury in the estuarine food web and exacerbate the existing mercury problem. This paper evaluates our present ability to predict the local and regional eects of restoration actions on mercury accumulation in aquatic food webs. A sport sh consumption advisory is in place for the Bay, and an advisory is under consideration for the Delta and lower Sacramento and San Joaquin rivers. Mercury concentrations in eggs of several water bird species from the Bay have exceeded the lowest observed eect level. A variety of mercury sources, largely related to historic mercury and gold mining, is present in the watershed and has created a spatially heterogeneous distribution of mercury in the Bay-Delta Estuary. Mercury exists in the environment in a variety of forms and has a complex biogeochemical cycle. The most hazardous form, methylmercury, is produced at a relatively high rate in wetlands and newly ooded aquatic habitats. It is likely that distinct spatial variation on multiple spatial scales exists in net methylmercury production in Bay-Delta tidal wetlands, including variation within each tidal wetland, among tidal wetlands in the same region, and among tidal wetlands in dierent regions. Understanding this spatial variation and its underlying causes will allow environmental managers to minimize the negative eects of mercury bioaccumulation as a result of restoration activities. Actions needed to reduce the uncertainty associated with this issue include a long term, multifaceted research eort, long term monitoring on local and regional scales, and careful evaluation of individual restoration projects with regard to potential increase of food web mercury.

Davis, J. R., M. D. May, et al. (2002). "Contaminant concentrations in sport fish from San Francisco Bay, 1997." Marine Pollution Bulletin 44: 1117-1129.

n 1997, seven sport fish species were sampled from seven popular fishing areas in San Francisco Bay. Mercury exceeded a human health screening value in 44 of 84 (52%) samples. All collected samples of leopard shark and striped bass exceeded the mercury screening value of 0.23 mug/g wet weight. PCBs exceeded the screening value in 51 of 72 (71%) samples. DDT, chlordane, and dieldrin, had lower numbers of samples above screening values: 16 of 72 (22%) for DDT, 11 of 72 (15%) for chlordanes, and 27 of 72 (37%) for dieldrin. Concentrations of PCBs and other trace organics were highest in white croaker and shiner surfperch, the two species with the highest fat content in their muscle tissue. Fish From one location, Oakland

Harbor, had significantly elevated wet weight concentrations of mercury, PCBs, DDTs, and chlordanes compared to other locations. Removal of skin from white croaker fillets reduced lipid concentrations by 27-49% and concentrations of trace organics by 33-40%. (C) 2002 Elsevier Science Ltd. All rights reserved.

De La Cruz, S., J.Y. Takekawa, K. Spragens, R. Golightly, G. Massey, M. Ziccardi, L. Henkel, and R.S. Larsen (2010). Survival of rehabilitated surf scoters oiled during the Cosco Busan spill on San Francisco Bay. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
On 7 November 2007, the M/V Cosco Busan released approximately 58,000 gallons of bunker oil into the San Francisco Bay (SFB) near the Oakland-San Francisco Bay Bridge. Surf scoters (Melanitta perspicillata) were the most affected bird species in this incident, and more than one thousand scoters were treated by the Oiled Wildlife Care Network in Cordelia, California. To evaluate post-release survival and the effects of rehabilitation on scoters, we compared winter survival of oiled and rehabilitated birds to that of 2 control treatment groups: un-oiled, rehabilitated; and un-oiled, non-rehabilitated scoters. Birds from each group were radio-marked and released in SFB. We conducted aerial telemetry flights 2 to 3 times a week for a total of 31 flights between 16 December 2007 and 7 April 2008 to determine location and mortality status of all marked birds. We used a live encounter – dead recovery modeling procedure in Program MARK to model surf scoter winter survival and used Akaike's Information Criterion (AICc) to rank and compare candidate fate models. The best-fitting model indicated that the probability of survival differed among treatment groups and over encounter occasions, and that there was an interaction between treatment group and time. We averaged across all models to determine cumulative winter survival estimates for each of the three treatment groups. The resulting estimates were lowest for oiled birds, and similar between un-oiled, rehabilitated and un-oiled, non-rehabilitated scoters. Our results provide information needed to help improve wildlife recovery after oil spills and other harmful events.

Dean, A. F., S. M. Bollens, et al. (2005). "Marshes as sources or sinks of an estuarine mysid: demographic patterns and tidal flux of Neomysis kadiakensis at China Camp marsh, San Francisco estuary." Estuarine, Coastal and Shelf Science 63(1-2): 1-11.
The population characteristics, seasonal abundance and tidal flux of Neomysis kadiakensis were studied to determine if tidal marshes serve as sources or sinks for mysids in China Camp, located in the San Francisco estuary. Monthly surveys of the zooplankton community were conducted during spring tide periods between May 2002 and May 2003, using a fyke net (500 gm mesh) fixed at the mouth of a fourth order tidal channel system in a tidal marsh. Mysids were collected and preserved hourly throughout full tidal cycles. Neomysis kadiakensis was the dominant mysid species, comprising 94-100% of mysids throughout the year. Monthly mean abundance of N. kadiakensis ranged from 14 mysids m(-3) in January 2003 to 244 mysids m(-3) in March 2003. Length frequency distributions indicated that reproduction and recruitment were nearly continuous, with abundance peaks occurring throughout the year (e.g., spring, summer and early fall). The resulting flux estimates during this period suggested that China Camp marsh was a sink for N. kadiakensis. The mean daily (ca. 24.8 h) fluxes of N. kadiakensis corresponded to an instantaneous daily population mortality rate within the marsh channel of 0.29 d(-1). Although all sizes and stages experienced a net import to the marsh, a significant positive relationship was observed between mysid length and mean annual flux, indicating that larger, mature mysids experienced a greater degree of tidal import to the marsh than smaller, juvenile mysids. These analyses suggest that size-specific predation, perhaps from fishes, shrimp, and/or birds may have had a disproportionate impact on large, mature mysids. Mortality rates in the marsh greatly exceeded the overall population growth rates, indicating that predation pressure on mysids was greater in the marsh than in the subtidal estuary. Mysids, therefore, supply a net flux of energy from the subtidal estuary to the marsh during spring tide series; however, the ultimate fate of this energy is unknown (remaining within the marsh system vs. export back to the estuary via trophic relay or other processes). (c) 2005 Elsevier Ltd. All rights reserved.

Deanovic, L., D. Markiewicz, M. Stillway, S. Fong, and I. Werner (2010). Evaluating the suitability of Hyalella azteca water column tests for the detection of insecticide toxicity. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Standard US EPA laboratory tests are used to monitor toxicity in surface waters, and the waterflea Ceriodaphnia dubia is considered the most sensitive test organism for detecting insecticide toxicity in freshwater environments. However, several inland water bodies within California typically have conductivities higher than this species can tolerate, and the relatively low sensitivity of the C. dubia test to current-use pesticides may mislead environmental risk managers. The euryhaline amphipod, Hyalella azteca, has the potential to be a valuable surrogate test species. Before tests with H. azteca can effectively replace or complement C. dubia tests in monitoring programs, information must be generated on the sensitivity of the species to toxicants, the method's ability to detect statistical differences, and the availability of protocols for Toxicity Identification Evaluation (TIE) procedures. This study compares the sensitivity of two water column toxicity tests, the chronic EPA C. dubia test and a 10-day H. azteca test. Organism sensitivity was evaluated through the generation of concentration effect data for several current-use insecticides for both species. Statistical sensitivity was evaluated by comparing the percent minimum significant differences (PMSDs). Factors affecting the identification of pyrethroid pesticides in TIE procedures were addressed, including adsorption to container walls, selecting effective piperonyl-butoxide (PBO) concentrations and quantifying synergism between PBO and pyrethroids. Our results show that H. azteca is the preferable test species for evaluating ecosystem health, especially when the conductivity range of samples falls between 200 and 10,000 µS/cm and pyrethroid insecticides are present. This study provides a solid foundation for integrating the 10-d water column test with H. azteca into future toxicity monitoring programs.

Deanovic, L., I. Werner, and D. Markiewicz (2010). Water toxicity monitoring in the Sacramento-San Joaquin Delta, California: 2006-2010. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Following the decline of numerous pelagic fish populations residing in the Sacramento-San Joaquin Delta of California, USA, a monitoring program was initiated to identify the extent and distribution of toxicity. Biweekly toxicity tests were performed on water samples from sixteen sites using the resident amphipod, Hyalella azteca. In addition, during March - May, water from five sites (340, Cache-Lindsay, Hood, Light 55, and Suisun) was tested with larval delta smelt (Hypomesus transpacificus). In situ monitoring was conducted at two DWR water quality monitoring stations (Rough & Ready Island on the San Joaquin River and Hood on the Sacramento River) using H. transpacificus, fathead minnows (Pimephales promelas), and H. azteca. Invertebrate tests were performed with and without the addition of PBO. Toxicity data obtained to date suggest that water quality is at times compromised in some areas of the Delta. Insecticides and ammonia and/or other effluent-associated contaminants likely contributed to the observed toxicity to H. azteca. The results of this project will be used to geographically focus management actions in the Delta and assist in identifying the sources and quantifying the effects of contaminants on aquatic species of concern.

Decho, A. W. and S. N. Luoma (1991). "Time-courses in the retention of food material in the marine bivalves Macoma balthica and Potamocorbula amurensis: significance to the absorption of carbon and chromium." Marine Ecology Progress Series 78: 303-314.
Time courses for ingestion, retention and release via feces of microbial food was investigated using 2 bivalves with different feeding strategies, Potamocorbula amurensis and Macoma balthica. The results showed 2 pathways for the uptake of food material in these clams. The first is represented by an initial label pulse in the feces. The second pathway operates over longer time periods. Inert super(51)Cr-labeled beads were used to determine time frames for these pathways. The first pathway, involving extracellular digestion and intestinal uptake, is relatively inefficient in the digestion of bacterial cells by P. amurensis but more efficient in M. balthica . The second pathway, involving intracellular digestion

within the digestive gland of both clams, was highly efficient in absorbing bacterial carbon, and was responsible for most chromium uptake. Differences in the overall retention of microbial super(51)Cr and super(14)C relate not to gut-passage times but to the processing and release strategies of the food material by these 2 clams.

Decho, A. W. and S. N. Luoma (1994). "Humic and fulvic acids: sink or source in the availability of metals to the marine bivalves Macoma balthica and Potamocorbula amurensis?" Marine Ecology Progress Series 108: 133-145.
Humic acids (HA) and fulvic acids (FA) are common forms of organic matter in marine sediments, and are routinely ingested by deposit- and suspension-feeding animals. These compounds may be a sink for metals, implying that once metals are bound to humic substances they are no longer available to food webs. A series of experiments was conducted to quantitatively examine this premise using 2 estuarine bivalves from San Francisco Bay, USA: the suspension feeder Potamocorbula amurensis and the facultative deposit feeder Macoma balthica. HA and FA, isolated from marine sediments, were bound as organic coatings to either hydrous ferric oxides (HFO) or silica particles. Cd and Cr(III) were adsorbed to the organic coatings or directly to uncoated HFO and silica particles. Pulse-chase laboratory feeding experiments using super(109)Cd and super(51)Cr(III) were then conducted to determine absorption efficiencies of Cd and Cr for individual specimens using each of the particle types. The results demonstrated that: (1) absorption of Cr(III) from all types of non-living particles was consistently low (< 11 %). Ingested Cd showed greater bioavailability than Cr (III), perhaps due to differences in metal chemistry. (2) Bivalves absorbed Cd bound to uncoated HFO or silica particles (i.e. with no HA or FA present). (3) The presence of organic coatings on particles reduced Cd bioavailability compared with uncoated particles. (4) Both geochemical and biological conditions affected the food chain transfer of Cd.

Decho, A. W. and S. N. Luoma (1996). "Flexible digestion strategies and trace metal assimilation in marine bivalves." Limnology and Oceanography 41(3): 568-572.
Pulse-chase experiments show that two marine bivalves take optimal advantage of different types of particulate food by varying food retention time in a flexible two-phase digestive system. For example, carbon is efficiently assimilated from bacteria by subjecting nearly all the ingested bacteria to prolonged digestion. Prolonging digestion also enhances assimilation of metals, many of which are toxic in minute quantities if they are biologically available. Detritus-feeding aquatic organisms have always lived in environments naturally rich in particle-reactive metals. We suggest that avoiding excess assimilation of metals could be a factor in the evolution of digestion strategies. We tested that suggestion by studying digestion of particles containing different Cr concentrations. We show that bivalves are capable of modifying the digestive processing of food to reduce exposure to high, biologically available, Cr concentrations. The evolution of a mechanism in some species to avoid high concentrations of metals in food could influence how effects of modern metal pollution are manifested in marine ecosystems.

Dege, M. and L. R. Brown (2004). Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 49-65.
We analyzed data on spring and summertime larval and juvenile fish distribution and abundance in the upper San Francisco Estuary (SFE), California between 1995 and 2001. The upper SFE includes the tidal freshwater areas of the Sacramento-San Joaquin Delta downstream to the euryhaline environment of San Pablo Bay. The sampling period included years with a variety of outflow conditions. Fifty taxa were collected using a larval tow net. Two common native species, delta smelt Hypomesus transpacificus and longfin smelt Spirinchus thaleichthys, and four common alien taxa, striped bass Morone saxatilis, threadfin shad Dorosoma petenense, gobies of the genus Tridentiger, and yellowfin goby Acanthogobius flavimanus, were selected for detailed analysis. Outflow conditions had a strong influence on the geographic distribution of most of the species, but distribution with respect to the 2 psu isohaline (X2) was not affected. The distribution patterns of delta smelt, longfin

smelt, and striped bass were consistent with larvae moving from upstream freshwater spawning areas to downstream estuarine rearing areas. There were no obvious relationships of outflow with annual abundance indices. Our results support the idea of using X2 as an organizing principle in understanding the ecology of larval fishes in the upper SFE. Additional years of sampling will likely lead to additional insights into the early life history of upper SFE fishes.

DeGeorge, J., S. Grinbergs, and R. Rachiele (2010). Local and delta-wide hydrodynamic impacts of large scale tidal marsh restoration. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The RMA Bay-Delta model is being used to evaluate changes in tidal flows and transport associated with large scale tidal marsh restoration proposed in the Bay Delta Conservation Plan (BDCP). Restoration areas are represented as two-dimensional depth-averaged flow regions and include Suisun Marsh, Cache Slough, West Delta, East Delta and South Delta regions. Restoration is considered at three time horizons with the largest restored acreage of approximately 65,000 acres occurring 40-50 years in the future. Opening large areas to tidal inundation can have a dramatic impact on flows and stage range in channels near the restoration site as well impacting stage range and net flow balances across the Delta. Adding large new restorations sites can mute the stage range significantly, reducing inter-tidal area in existing tidal marsh and in planned restoration sites when conveyance is restricted. The geometry of the channels and restored area may be expected to change over time through scour or deposition. Increasing the area open to filling and draining with the tides may lead to changes in channel geometry through scour as the channel adapts to the new demand for tidal flow. Subsidence and sea level rise will generally lead to a much larger area open to filling and draining than there was when the levees were originally constructed. This talk will present the approach to tidal marsh modeling, an overview of flow, stage and transport impacts, and investigation of changes to geometry over time.

DeGeorge, J., S. Grinbergs, and R. Rachiele (2010). Simulation of hydrodynamic responses for evaluation of infrastructure and restoration investment risks under climate change. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Under the Bay Delta Conservation Plan (BDCP) Proposed Project, large-scale tidal marsh restoration is proposed for various areas of the Delta with a strong emphasis on areas in the Suisun Marsh and Cache Slough regions. As the major element to water operations, the Proposed Project also includes the development and operation of five new water diversion intakes to be located on the Sacramento River in the vicinity of Hood. Resource Management Associates has performed 2-D hydrodynamic and salinity transport simulations to assess the risks to the proposed tidal marsh restoration and the north Delta intakes due to large-scale levee failure and long-term sea level rise. Two levee failure events have been considered including a three island failure scenario and a larger failure scenario that might be associated with a magnitude 6.7 earthquake on the Hayward fault. For the purposes of the BDCP planning for the Habitat Conservation Plan and associated permit, sea level rise was considered for the period extending to the year 2060 (50-year permit). However, for the evaluation of investment risk it is necessary to consider that the infrastructure (restoration and intakes) will function for much longer than the permit. For this reason the most extreme sea level rise currently estimated for the year 2100 of 140 cm along with increases in tidal amplitude was used in this risk assessment. Model results are analyzed with respect to tidal stage, flows and velocities, as well as salinity distribution changes in the Delta.

Del Real, C., M. Workman, and J. Merz (2010). Pathways, timing and rates of migration for hatchery and natural origin steelhead, Oncorhynchus mykiss, from the lower Mokelumne River, Ca. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The lower Mokelumne River (LMR), in the Central Valley of California, supports a population of natural Oncorhynchus mykiss, and the Mokelumne River Fish Hatchery contributes hatchery produced smolts to the system annually. We compared migratory patterns of LMR O. mykiss of natural and hatchery origin over a three year

period. Specifically we looked at timing, rates, and pathway utilization under variable release locations in tidal and non-tidal habitats in the Mokelumne River and Sacramento San Joaquin Estuary. Data reported is recovered from receiver locations deployed in the non-tidal reaches of the LMR, as well as receivers deployed throughout the Estuary by participants of the Central Valley Fish Tracking Consortium. Our study provides valuable information on differences in hatchery and wild O. mykiss migration characteristics and provides unique insight into migratory behavior of little studied non-Sacramento River origin salmonids.

del Rosario, R. B., Y.J. Redler, K. Newman, P.L. Brandes, T. Sommer, K. Reece, and R. Vincik (2013). "Migration Patterns of Juvenile Winter-run-sized Chinook Salmon (Oncorhynchus tshawytscha) through the Sacramento-San Joaquin Delta." San Francisco Estuary and Watershed Science 11(1): 22.

The decline of Sacramento River winter-run Chinook salmon (Oncorhynchus tshawytscha)
remains one of the major water management issues in the Sacramento River. Few field studies
have been published on winter-run, leaving gaps in our knowledge about their life history. This
is especially true in the Sacramento–San Joaquin Delta, which provides essential rearing and
migratory habitats for winter-run, and serves as the center of water operations for California. Using
long-term monitoring data that identified winter-run-sized fish ("winter-run") using length-at-date
criteria, we examined patterns of juvenile migration in terms of geographic distribution, timing,
numbers, and residence times. We analyzed the role of flow, turbidity, temperature, and adult
escapement on the downstream movement ("migration") of winter-run. Winter-run passed Knights
Landing (rkm 144 or 51 rkm upstream of the Delta) between October and April, with substantial
variation in peak time of entry that was strongly associated with the first high flows of the migration
season. Specifically, the first day of flows of at least 400 m3 s-1 at Wilkins Slough (rkm 190)
coincided with the first day that at least 5% of the annual total catch was observed at Knights
Landing. While the period during which winter-run left the Delta spanned several months based on
Chipps Island (rkm 29) catch data, the median catch typically occurred over a narrow window in
March. Differences in timing of cumulative catch at Knights Landing and Chipps Island indicate that
apparent residence time in the Delta ranges from 41 to 117 days, with longer apparent residence
times for juveniles arriving earlier at Knights Landing. We discuss the potential importance of the
Yolo Bypass floodplain as an alternative rearing and migratory corridor, contingent on the timing,
duration, and magnitude of floodplain inundation. These results carry implications for habitat
restoration and management of Sacramento River flows.

Deng, D.-F., K. Zheng, et al. (2010). "Toxic threshold of dietary microcystin (-LR) for quart medaka." Toxicon 55(4): 787-794.

This study was designed to estimate the toxic threshold of male and female fish to microcystins based on different biomarkers. Japanese medaka (Oryzias latipes) were fed dietary Microcystin-LR (0, 0.46, 0.85, 2.01 and 3.93 [mu]g MC-LR/g dry diet for 8 weeks at 25 °C. The results revealed that dietary MC-LR inhibited growth at the end of 8 weeks. The survival of embryos and the RNA/DNA ratio of whole fish decreased significantly (P < 0.05) in fish fed 3.93 [mu]g MC-LR/g dry diet.

Heat shock protein (Hsp60) expression was induced in the liver of female and male fish fed diets containing >=0.85 and 0.46 [mu]g MC-LR/g diet, respectively. The activity of liver caspase 3/7 was significantly higher in female fish fed 3.93 [mu]g MC-LR/g diet and in males fed 2.01 MC-LR [mu]g/g dry diet than fish fed the control diet. The threshold for inhibition of liver protein phosphatase expression was lower in female (2.01 [mu]g/g diet) than that in male fish (3.93 [mu]g/g diet). Histopathological examination showed significant single-cell necrosis in female and male medaka fed diets containing 0.85 and 3.93 [mu]g MC-LR/g diet, respectively. Based on different biomarkers, this study demonstrated that dietary MC-LR is toxic to Medaka and the effects are gender dependent.

Denton, R. A. (1993). Accounting for antecedent conditions in seawater intrusion modeling - applications for the San Francisco Bay-Delta, ASCE: 448-453.

Denton, R. A. (1993). Predicting water quality at municipal water intakes - Part 1: application to the Contra Costa Canal intake, ASCE: 809-814.

Dettinger, M. D. (2005). "From climate-change spaghetti to climate-change distributions for 21st Century California." San Francisco Estuary and Watershed Science 3(1): [vp].

The uncertainties associated with climate-change projections for California are unlikely to disappear any time soon, and yet important long-term decisions will be needed to accommodate those potential changes. Projection uncertainties have typically been addressed by analysis of a few scenarios, chosen based on availability or to capture the extreme cases among available projections. However, by focusing on more common projections rather than the most extreme projections (using a new resampling method), new insights into current projections emerge: (1) uncertainties associated with future greenhouse-gas emissions are comparable with the differences among climate models, so that neither source of uncertainties should be neglected or underrepresented; (2) twenty-first century temperature projections spread more, overall, than do precipitation scenarios; (3) projections of extremely wet futures for California are true outliers among current projections; and (4) current projections that are warmest tend, overall, to yield a moderately drier California, while the cooler projections yield a somewhat wetter future. The resampling approach applied in this paper also provides a natural opportunity to objectively incorporate measures of model skill and the likelihoods of various emission scenarios into future assessments.

Dettinger, M. D. and D. R. Cayan (1995). "Large-scale atmospheric forcing of recent trends toward early snowmelt runoff in California." Journal of Climate 8: 606-623.

Since the late 1940s, snowmelt and runoff have come increasingly early in the water year in many basins in northern and central California. This subtle trend is most pronounced in moderate-altitude basins, which are sensitive to changes in mean winter temperatures. Such basins have broad areas in which winter temperatures are near enough to freezing that small increases result initially in the formation of less snow and eventually in early snowmelt. In moderate-altitude basins of California, a declining fraction of the annual runoff has come in April-June. This decline has been compensated by increased fractions of runoff at other, mostly earlier, times in the water year. Weather stations in central California, including the central Sierra Nevada, have shown trends toward warmer winters since the 1940s. A series of regression analyses indicate that runoff timing responds equally to the observed decadal-scale trends in winter temperature and interannual temperature variations of the same magnitude, suggesting that the temperature trend is sufficient to explain the runoff-timing trends. The immediate cause of the trend toward warmer winters in California is a concurrent, long-term fluctuation in winter atmospheric circulations over the North Pacific Ocean and North America that is not immediately distinguishable from natural atmospheric variability. The fluctuation began to affect California in the 1940s, when the region of strongest low-frequency variation of winter circulations shifted to a part of the central North Pacific Ocean that is teleconnected to California temperatures. Since the late 1940s, winter wind fields have been displaced progressively southward over the central North Pacific and northward over the west coast of North America. These shifts in atmospheric circulations are associated with concurrent shifts in both West Coast

air temperatures and North Pacific sea surface temperatures.

Dettinger, M. D., D. R. Cayan, et al. (1998). "North-south precipitation patterns in western North America on interannual-to-decadal timescales." Journal of Climate 11: 3095-3111.

The overall amount of precipitation deposited along the West Coast and western cordillera of North America from 25 degrees to 55 degrees N varies from year to year, and superimposed on this domain-average variability are varying north-south contrasts on timescales from at least interannual to interdecadal. In order to better understand the north-south precipitation contrasts, their interannual and decadal variations are studied in terms of how much they affect overall precipitation amounts and how they are related to large-scale climatic patterns. Spatial empirical orthogonal functions (EOFs) and spatial moments (domain average, central latitude, and latitudinal spread) of zonally averaged precipitation anomalies along the westernmost parts of North America are analyzed, and each is correlated with global sea level pressure (SLP) and sea surface temperature series, on interannual (defined here as 3-7 yr) and decadal (>7 yr) timescales. The interannual band considered here corresponds to timescales that are particularly strong in tropical climate variations and thus is expected to contain much precipitation variability that is related to El Nino-Southern Oscillation; the decadal scale is defined so as to capture the whole range of long-term climatic variations affecting western North America.

Zonal EOFs of the interannual and decadal filtered versions of the zonal-precipitation series are remarkably similar. At both timescales, two leading EOFs describe I) a north-south seesaw of precipitation pivoting near 40 degrees N and 2) variations in precipitation near 40 degrees N, respectively. The amount of overall precipitation variability is only about 10% of the mean and is largely determined by precipitation variations around 40 degrees-45 degrees N and most consistently influenced by nearby circulation patterns; in this sense, domain-average precipitation is closely related to the second EOF. The central latitude and latitudinal spread of precipitation distributions are strongly influenced by precipitation variations in the southern parts of western North America and are closely related to the first EOF Central latitude of precipitation moves south (north) with tropical warming (cooling) in association with midlatitude western Pacific SLP variations, on both interannual and decadal timescales. Regional patterns and zonal averages of precipitation-sensitive tree-ring series are used to corroborate these patterns and to extend them into the past and appear to share much long- and short-term information with the instrumentally based zonal precipitation EOFs and moments.

Deverel, S., C. Jones, D. Leighton, J. Dudas, B. Brock, G. Bawden, S. Hensley, and T. Ingrum (2010). Recent advances in subsidence measurement and mitigation. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Subsidence of Delta organic soils and levees is a primary landscaping altering process affecting ecosystem sustainability. Key consequences include increased volume below sea level, drainage loads of water quality constituents of concern, seepage onto islands and decreased arability and levee stability. To estimate and understand recent subsidence, we collected elevation and soils data on Bacon and Sherman islands at locations of previous elevation measurements. Measured subsidence rates on Sherman Island from 1988 to 2006 averaged 1.23 cm yr-1 (0.5 in yr-1) and ranged from 0.7 to 1.7 cm year-1. Subsidence rates on Bacon Island from 1978 to 2006 averaged 2.2 cm year-1 and ranged from 1.5 to 3.7 cm year-1. Changing land-management practices and decreasing soil organic matter content have resulted in decreasing subsidence rates since the early and mid 1900's. Since 2009, we have experimented with acquiring monthly airborne synthetic aperture radar interferometry (UAVSAR) to measure sub centimeter changes in Delta land surface elevations at 10 m X 10 m surface area resolution. We are using repeat pass interferograms to assess short-term changes in the Delta and applying permanent scatterers InSAR (PInSAR) technique to image longer-term motion of individual targets from multiple look directions on single flight lines. This is providing robust information about subsidence in agricultural areas. Preliminary flight data shows widespread coherence and reasonable agreement with ground truth measurements. To help understand causes and estimate future subsidence, we developed a model that effectively simulates subsidence and carbon loss from organic soils. We predict that elevation decreases from 2007 to 2050 will range from a few cm to over 1.3 m. During the next 40 years, we estimated the increase in volume of the land surface that is below sea level to be 346,956,000 million m3 (281,300 ac-ft). Recent data indicate that rice cultivation will arrest subsidence.

Deverel, S. J., D. A. Leighton, et al. (2007). "Processes Affecting Agricultural Drainwater Quality and Organic Carbon Loads in California's Sacramento-San Joaquin Delta." San Francisco Estuary and Watershed Science 5(2): Article 2.

From 2000 to 2003 we quantified drain flow, drain-and ground-water chemistry and hydrogeologic conditions on Twitchell Island in the Sacramento-San Joaquin Delta. The primary objective was to quantify processes affecting organic carbon concentrations and loads in agricultural drainage water. We collected physical and chemical data in southern and northern areas: TN and TS, respectively. Corn grew in both areas during the spring and summer. The peat soils in the TN area are more decomposed than those in the TS area. Results elucidate processes affecting drain flow and concentrations under varying hydrologic conditions. During May through November, groundwater flows from the permanently saturated zone to drainage ditches, and the resulting average drainage-water quality and dissolved organic carbon (DOC) concentration was similar to the groundwater; the median DOC loads in the TN and TS study areas ranged from 9 to 27 g C/ha-day. The major ion chemistry and stable isotope data confirmed that groundwater was the primary source of drainflow. In contrast, during December through April the drainwater is supplied from the shallow, variably saturated soil-zone. The DOC concentrations, major-ion chemistry, and stable isotope data indicate that the shallow-zone water is partially evaporated and oxidized. Higher flows and DOC concentrations during these months result in higher median DOC loads, which ranged from 84 to 280 g C/ha-day.

During December through April, increasing groundwater levels in the shallow peat layers and mobilization of organic carbon result in high drain flow and increased trihalomethane precursor concentrations and loads. On a per mass DOC basis, drain water collected during high flow periods is less likely to form THMs than during low flow periods. However, the high flows and subsequent high concentrations contribute to substantially higher trihalomethane precursor and DOC loads.

Dickens, J. L. (2006). "Genetic analysis of temporal and spatial disjunction in populations of yellowfin goby, Acanthogobius flavimanus." Masters Abstracts International 44(6): 50.

Yellowfin goby, Acanthogobius flavimanus, is a demersal, estuarine fish native to eastern Asia that has extended its distribution to estuaries of the eastern Pacific Ocean. This provides an opportunity to study the effects of founder events that result in spatial disjunction. The goal of this thesis is to determine the extent to which exogenous reinforcement, or self-recruitment, contributes to the maintenance of four populations of yellowfin goby in estuaries using data from microsatellite loci. Using MIGRATE, effective population sizes were estimated for Upper Newport Bay (168), Bolsa Chica (100), San Francisco Bay (171) and Tokyo Bay (199). Estimates of variance effective size for Newport Bay (7), Bolsa Chica (38) and San Francisco Bay (86) were also made. Using Arlequin, non-significant pairwise R sub(ST) comparisons were observed for Bolsa Chica-Tokyo Bay and San Francisco-Tokyo Bay. Based on migration rates and allelic diversity, Tokyo Bay is the evident source for all invasive populations in California. Based on R sub(ST) comparisons, populations in San Francisco Bay and Bolsa Chica were directly established from Tokyo Bay, while the Upper Newport Bay population is probably the result of emigration from Bolsa Chica.

Dill, W. A. and A. J. Cordone (1997). History And Status of Introduced Fishes In California, 1871 - 1996. Sacramento, California Department of Fish and Game.

Unlike previous histories on the subject (the last being in 1976), this one is fully documented by primary references to the original publication or other sources. There are also explanations as to why some of the previous errors occurred.

The detailed history of each introduction, including the primary references, is given. The subsequent history and status of each species in California is given. The attitude of administrators, ichthyologists, fish culturists, fishery biologists, fishermen, and the public toward each introduction is given, and there is a discussion of their value. There is, with respect to California, a review of the present regulations concerning introduced fishes, and a prognostication of the future concerning them.

Approximately 111 full species of freshwater and euryhaline fishes occur in California. (Salton Sea fishes are excluded.) of these, 53 have been introduced from without the state and have been established successfully. Another five subspecies or races have become established. Twelve introduced fishes have uncertain status. Thirty-nine, including one marine fish which was deliberately introduced, have achieved no lasting success. Eight introduced fishes are listed as "hypothetical." Five were scheduled for introduction, but the introductions were never completed. Three species have been listed erroneously in scientific papers as having been introduced. About 26 other species have been formally suggested as introductions. Three species are likely candidates for introduction.

Dinehart, R. L. and J. R. Burau (2005). "Repeated surveys by acoustic Doppler current profiler for flow and sediment dynamics in a tidal river." Journal of Hydrology 314(1-4): 1-21.

A strategy of repeated surveys by acoustic Doppler current profiler (ADCP) was applied in a tidal river to map velocity vectors and suspended-sediment indicators. The Sacramento River at the junction with the Delta Cross Channel at Walnut Grove, California, was surveyed over several tidal cycles in the Fall of 2000 and 2001 with a vessel-mounted ADCP. Velocity profiles were recorded along flow-defining survey paths, with surveys repeated every 27 min through a diurnal tidal cycle. Velocity vectors along each survey path were interpolated to a three-dimensional Cartesian grid that conformed to local bathymetry. A separate array of vectors was interpolated onto a grid from each survey. By displaying interpolated vector grids sequentially with computer animation, flow dynamics of the reach could be studied in three-dimensions as flow responded to the tidal cycle. Velocity streamtraces in the grid showed the upwelling of flow from the bottom of the Sacramento River channel into the Delta Cross Channel. The sequential display of vector grids showed that water in the canal briefly returned into the Sacramento River after peak flood tides, which had not been known previously. In addition to velocity vectors, ADCP data were processed to derive channel bathymetry and a spatial indicator for suspended-sediment concentration. Individual beam distances to bed, recorded by the ADCP, were transformed to yield bathymetry accurate enough to resolve small bedforms within the study reach. While recording velocity, ADCPs also record the intensity of acoustic backscatter from particles suspended in the flow. Sequential surveys of backscatter intensity were interpolated to grids and animated to indicate the spatial movement of suspended sediment through the study reach. Calculation of backscatter flux through cross-sectional grids provided a first step for computation of suspended-sediment discharge, the second step being a calibrated relation between backscatter intensity and sediment concentration. Spatial analyses of ADCP data showed that a strategy of repeated surveys and flow-field interpolation has the potential to simplify computation of flow and sediment discharge through complex waterways. The use of trade, product, industry, or firm names in this report is for descriptive purposes only and does not constitute endorsement of products by the US Government. (c) 2005 Elsevier B.V. All rights reserved.

Doblin, M. A., S. B. Baines, et al. (2006). "Sources and biogeochemical cycling of particulate selenium in the San Francisco Bay estuary." Estuarine, Coastal and Shelf Science 67(4): 681-694.

Abstract: As part of a study of estuarine selenium cycling, we measured the concentration, chemical form (speciation), and distribution of particulate selenium under various river flow conditions in the North San Francisco Bay (from the Golden Gate to the Sacramento and San Joaquin Rivers). We also conducted laboratory studies on the accumulation of selenium by phytoplankton, the critical first step in the transformation of dissolved to particulate selenium. Total particulate selenium concentration in the North SF Bay was relatively constant between high and low flow periods, ranging spatially from 0.05 to 0.35 nmol l(-1) and comprising between 5 and 12% of the total water column selenium inventory. Mean concentrations were generally highest in the Carquinez Strait-Suisun Bay region (salinity 0-17) and lowest in Central Bay. However, selenium content of suspended particles varied with river flow, with higher content during low flow (9.76 +/- 4.17 nmol g(-1); mean sd; n = 67) compared to high flow (7.10 +/- 4.24 nmol g(-1): n = 39). Speciation analyses showed that most particulate selenium is organic selenide (45 +/- 27%), with a smaller proportion (typically < 30%) of adsorbed selenite + selenate and a varying proportion (35 +/- 28%) of elemental selenium. Based on the amount of elemental selenium in the seston (total suspended material), we calculate that resuspension of estuarine sediments could contribute 29-100% of particulate selenium in the water column. While selenium content of SF Bay seston (> 0.4 mu m) is relatively unenriched compared to phytoplankton (13.6-155 nmol g(-1) dry weight) on a mass basis, when normalized to carbon or nitrogen, seston contains a similar selenium concentration to SF Bay sediments or phytoplankton cultures. SF Bay seston is thus comprised of selenium-rich phytoplankton and phyto-detritus, but also inorganic clay mineral particles that effectively "dilute" total particulate selenium. Selenium concentrations in algal cultures (11 species) exposed to 90 nmol l(-1) selenite show relatively large differences in selenium accumulation, with the diatoms, chlorophytes and cryptophytes generally having lower selenium cell content (3.8 +/- 2.7 x 10(-9) nmol selenium cell(-1)) compared to the dinoflaggellates (193 +/- 73 x 10(-9) nmol selenium cell(-1)). Because phytoplankton are such a rich (but variable) source of selenium, their dynamics could have a profound effect on the particulate selenium inventory in the North SF Bay.

Domagalski, J. (2001). "Mercury and methylmercury in water and sediment of the Sacramento River Basin, California." Applied Geochemistry 16(15): 1677-1691.

Mercury (Hg) and methylmercury (CH sub(3)Hg super(+)) concentrations in streambed sediment and water were determined at 27 locations throughout the Sacramento River Basin, CA. Mercury in sediment was elevated at locations downstream of either Hg mining or Au mining activities where Hg was used in the recovery of Au. Methylmercury in sediment was highest (2.84 ng/g) at a location with the greatest wetland land cover, in spite of lower total Hg at that site relative to other river sites. Mercury in unfiltered water was measured at 4 locations on the Sacramento River and at tributaries draining the mining regions, as well as agricultural regions. The highest levels of Hg in unfiltered water (2248 ng/l) were measured at a site downstream of a historic Hg mining area, and the highest levels at all sites were measured in samples collected during high streamflow when the levels of suspended sediment were also elevated. Mercury in unfiltered water exceeded the current federal and state recommended criterion for protection of aquatic life (50 ng/l as total Hg in unfiltered water) only during high streamflow conditions. The highest loading of Hg to the San Francisco Bay system was attributed to sources within the Cache Creek watershed, which are downstream of historic Hg mines, and to an unknown source or sources to the mainstem of the Sacramento River upstream of historic Au mining regions. That unknown source is possibly associated with a volcanic deposit. Methylmercury concentrations also were dependent on season and hydrologic conditions. The highest levels (1.98 ng/l) in the Sacramento River, during the period of study, were measured during a major flood event.

Domagalski, J. L., and K.M. Kuivila (1993). "Distributions of pesticides and organic contaminants between water and suspended sediment, San Francisco Bay, California." Estuaries and Coasts 16(3A): 416-426.

Suspended-sediment and water samples were collected from San Francisco Bay in 1991 during low river discharge and after spring rains. All samples were analyzed for organophosphate, carbamate, and organochlorine pesticides; petroleum hydrocarbons; biomarkers; and polynuclear aromatic hydrocarbons. The objectives were to determine the concentrations of these contaminants in water and suspended sediment during two different hydrologic conditions and to determine partition coefficients of the contaminants between water and sediment. Concentrations of hydrophobic contaminants, such as polynuclear aromatic hydrocarbons, varied with location of sample collection, riverine discharge, and tidal cycle. Concentrations of hydrophobic contaminants in suspended sediments were highest during low river discharge but became diluted as agricultural soils entered the bay after spring rains. Polynuclear aromatic hydrocarbons defined as dissolved in the water column were not detected. The concentrations sorbed on suspended sediments were variable and were dependent on sediment transport patterns in the bay. In contrast, the relatively hydrophilic organophosphate pesticides, such as chlorpyrifos and diazinon, has a more uniform concentration in suspended sediment. These pesticides were detected only after spring rains. Most of the measured diazinon, at least 98% for all samples, was in the dissolved phase. Measured partition coefficients for diazinon generally were uniform, which suggests that suspended-sediment concentrations were close to equilibrium with dissolved concentrations. The concentration of diazinon sorbed to suspended sediments, at any given sampling site, was driven primarily by the more abundant solution concentration. The concentrations of diazinon sorbed to suspended sediments, therefore, were independent of the patterns of sediment movement.

Domagalski, J. L. (1996). "Occurrence of dicofol in the San Joaquin River, California." Bulletin of Environmental Contamination and Toxicology 57(2): 284-291.

The San Joaquin River and its tributaries were sampled intensively for pesticides during the irrigation season-April through October of 1993. The purpose of the sampling was to determine the occurrence of pesticides defined operationally as those dissolved in the water column. A pesticide detected frequently in these samplings was dicofol (2,2,2-trichloro-1,1-bis(4-chlorophenyl)ethanol). The purpose of this paper is to present the results of dicofol occurrence in the San Joaquin River and its tributaries, during the irrigation season of 1993, and to relate that occurrence to land use within the basin and to the physical properties of dicofol.

Domagalski, J. L., N.M. Dubrovsky, and C.R. Kratzner (1997). "Pesticides in the San Joaquin River, California: Inputs from the dormant sprayed orchards." Journal of Environmental Quality 26(2): 454-465.

Rainfall-induced runoff mobilized pesticides to the San Joaquin River and its tributaries during a 3.8-cm rainstorm beginning the evening of 7 February and lasting through the morning of 8 Feb. 1993. Two distinct peaks of organophosphate pesticide concentrations were measured at the mouth of the San Joaquin River. These two peaks were attributed to contrasts between the soil texture, basin size, pesticide-use patterns, and hydrology of the eastern and western San Joaquin Valley. The fine soil texture and small size of the western tributary basins contributed to rapid runoff. In western valley streams, diazinon concentrations peaked within hours of the rainfall's end and then decreased because of a combination of dilution with pesticide-free runoff from the nearby Coast Ranges and decreasing concentrations in the agricultural runoff. Peak concentrations for the Merced River, a large tributary of the eastern San Joaquin Valley, occurred at least a day later than those of the western tributary streams. That delay may be due to the presence of well-drained soils in the eastern San Joaquin Valley, the larger size of the Merced River drainage basin, and the management of surface-water drainage networks. A subsequent storm on 18 and 19 February resulted in much lower concentrations of most organophosphate pesticides suggesting that the first storm had mobilized most of the pesticides that were available for rainfall-induced transport.

Domagalski, J. L. (1997). "Results of prototype surface water network design for pesticides developed for the San Joaquin River Basin, California." Journal of Hydrology (Amsterdam) 192(1-4): 33-50.

A nested surface water monitoring network was designed and tested to measure variability in pesticide concentrations in the San Joaquin River and selected tributaries during the irrigation season. The network design and sampling frequency necessary for determining the variability and distribution in pesticide concentrations were tested in a prototype study. The San Joaquin River Basin, California, was sampled from April to August, 1992, a period during the irrigation season where there was no rainfall. Orestimba Creek, which drains a part of the western San Joaquin Valley, was sampled three times per week for 6 weeks, followed by a once per week sampling for 6 weeks, and then three times per week sampling for 6 weeks. A site on the San Joaquin River near the mouth of the basin, and an irrigation drain of the eastern San Joaquin Valley, were sampled weekly during the entire sampling period. Pesticides were most often detected in samples collected

from Orestimba Creek. This suggests that the western valley was the principal source of pesticides to the San Joaquin River during the irrigation season. Irrigation drainage water was the source of pesticides to Orestimba Creek. Pesticide concentrations of Orestimba Creek showed greater temporal variability when sampled three times per week than when sampled once a week, due to variations in field management and irrigation. The implication for the San Joaquin River basin (an irrigation-dominated agricultural setting) is that frequent sampling of tributary sites is necessary to describe the variability in pesticides transported to the San Joaquin River.

Dombeck, G. D., M. W. Perry, et al. (1998). "Mass balance on water column trace metals in a free-surface-flow-constructed wetlands in Sacramento, California." Ecological Engineering 10(4): 313-339.
A mass balance has been performed on trace metals concentrations and hydrology observed between 1994 and 1996 at the Sacramento Demonstration Constructed Wetlands using a first-order areal plug flow model. Water losses to infiltration and evapotranspiration from a typical cell are estimated to average 35 and 7% of influent flow, respectively. The wetlands effluent metals concentrations consistently meet proposed discharge criteria. Annual total mass loadings for all trace metals average 14.0 kg ha super(-1) yr super(-1), 88% of which consists of zinc, copper, and nickel. Effluent metals leaving the wetland average 3.1 kg ha super(-1) yr super(-1), 79% of which consists of the same three metals. Annual vegetation harvest events do not appear to account for more than 5% of annual trace metals mass removal, although harvest does appear to represent a significant loss pathway for some metals like mercury, lead, nickel, and chromium. Metals mass removals resulting from first-order removal interactions within the wetland range from 27 to 81%, with the exception of arsenic and nickel which display poor mass removals in part due to their high dissolved concentrations. An average of 7.6 kg ha super(-1) yr super(-1), or 54% of influent metals loadings, is sequestered within the internal wetland compartments.

Donigian, A., B. Bicknell, and K.S. Rosselot (2010). Copper runoff to San Francisco Bay from brake pad wear debris – phase 2 watershed modeling analyses. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The Brake Pad Partnership has conducted a series of interconnected technical studies to determine whether or not copper from brake pads contributes significantly to copper in surface waters in the San Francisco Bay watershed. As part of the Partnership’s studies, air deposition modeling, watershed modeling (reported at the 2008 Bay-Delta conference), and bay modeling were conducted. The Partnership’s technical studies showed that brake pad wear debris is a significant contributor to copper in runoff to the San Francisco Bay, particularly in highly urbanized sub-watersheds. This paper reports on the Phase 2 of the watershed modeling efforts. The watershed modeling was conducted using the U.S. EPA's Hydrological Simulation Program-FORTRAN (HSPF) model to estimate the copper in runoff to the bay. Based on the Phase 1 modeling, the contribution of copper from brake pads to the total copper load in runoff to the bay is from 10% (for the brakes-low case) to 35% (for the brakes-high case). This follow-on Phase 2 effort was done to better understand the full extent of the contribution of copper from brakes on copper in runoff, and determine the timeframe over which reductions in copper from brakes will result in reductions of copper in surface waters. The buildup/washoff modeling technique used in the Phase 1 watershed modeling effort was modified to capture the copper that is lost from the buildup/washoff algorithm, and transferring that copper to a roadside buffer area, where it is subject to washoff to surface waters. Mean annual loads to the Bay increased from 0.5-3.5% over Phase 1 loads when the buffer area was assumed to be pervious, and 15-30% when impervious. The final portion of the Phase 2 modeling was conducted in order to help understand the length of time it will take for brake pad wear debris copper to wash out of California’s urban watersheds. Based on the model results, the answer to the question “How long will it take copper from brake pad wear debris to wash out of California’s urban watersheds?” is that it will take from 0 to 5 years for 80% and from 6 to 15 years for 95% of reductions in releases of copper from brake pad wear debris to be realized in urban surface waters in the San Francisco Bay area.

Downie, S. T., C.M. LeDoux-Bloom, K. Spivak, and F. Yee (2003). 2003 Albion River Basin assessment report. Sacramento, North Coast Watershed Assessment Program, CA Department of Fish and Game: 198 pp.

Downie, S. T., C.M. LeDoux-Bloom, and J. Richardson (2003). Gualala Basin implementation summary. Sacramento, Coastal Watershed Planning and Assessment Program, CA Department of Fish and Game: 55 pp.

Downie, S. T., C.M. LeDoux-Bloom, K. Spivak, and F. Yee (2004). Albion Basin Implementation summary. Sacramento, North Coast Watershed Assessment Program, CA Department of Fish and Game.

Downing, B., T. Kraus, B.A. Bergamaschi, S. Siegel, P. Bachand, and R. Fujii (2010). Linking trends in low dissolved oxygen events with dissolved organic matter quality using optical properties measurements in Northern Suisun Marsh. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Severe low dissolved oxygen (DO) events resulting from environmental conditions and management actions in some managed wetlands adversely impact the aquatic ecosystem of Suisun Marsh. Marsh drainage rich in dissolved organic matter (DOM) stimulates microbial activity increasing the biological oxygen demand in surrounding waters. Dissolved mercury in surface waters is often associated with DOM, influenced by DOM composition. Optical property measurements (absorbance and fluorescence) were used to provide quantitative and qualitative information about DOM. The specific UV absorbance normalized to DOC concentration (SUVA) was used as a proxy for aromatic content. The exponential shape of absorbance spectra (spectral slope, S) was used to identify compositional differences in DOM. Identification of fluorescent pairs or fluorophores in excitation - emission matrix (EEMs) using Parallel Factor Analysis (PARAFAC) further identified qualitative classes of DOM. The fluorescence index (FI) has been widely used to indicate relative contributions of algal versus terrestrial derived DOM. Results of this study indicate a mixture of terrestrially derived DOM sources (soil organic matter, vascular plants and waste water) as primary sources of labile carbon. Optical property measurements show that DOM is most bioavailable in the first few weeks of flooding and point to a mixture of terrestrially derived end-members—soil organic matter, vascular plants and waste water DOM—as primary sources of labile carbon to the wetlands. Changes in DOM amount and quality indicate that labile DOM is consumed in the first few weeks of flooding as biological and photochemical processes take place.

Downing-Kunz, M., and M. Stacey (2010). Physical interactions between floating macrophytes and environmental flows: implications for invasive plant management in the Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Invasive floating macrophytes are aquatic weeds that exert strong negative influences on an ecosystem owing to characteristics such as high growth rates aided by asexual reproduction, formation of dense floating mats that out-compete other plant species, and unanchored root systems that allow dispersal by passive drifting by on environmental flows. Water hyacinth (Eichhornia crassipes) is one such weed that has invaded freshwater systems worldwide, including the Sacramento-San Joaquin Delta (Delta). Water hyacinth causes significant problems in the Delta and is costly to control. Improved control strategies of water hyacinth are needed; this research examines physical interactions between plants and surrounding flows to better understand transport mechanisms that govern regional dispersal. Experiments in an open channel flume and a wind tunnel were conducted using live water hyacinth plants to observe flow-induced forces and surrounding flow fields for different mat configurations. Forces were measured directly using a strain gauge and velocities were measured using an acoustic Doppler velocimeter (water) and a sonic anemometer (air). Over similar Reynolds number regimes, water drag forces exceed air drag forces for a given mat and water drag coefficients are greater than wind drag coefficients. Drag coefficients for water and air decrease with increasing mat Reynolds number, although water drag coefficients have a steeper decrease. Mean drag coefficient increases as mat length to height ratio (L/D) increases, suggesting

frictional drag is important. The presence of water hyacinth mats in a channel causes deflection of air and water flows around the mat structure and increases turbulence in both fluids. These results suggest that water-driven transport, when present, is the dominant mechanism for water hyacinth dispersal, although ambient flow conditions at source locations must also be considered. This research forms the basis for future development of a predictive model for floating macrophyte dispersal based on physical processes.

Doyle, L., and W. Fleenor (2010). Flooded island ecosystems: Physical drivers of biological productivity following levee breaches on Sacramento-San Joaquin Delta Islands. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The Sacramento-San Joaquin Delta is the heart of California’s water supply system and the base of an important, but quickly declining ecosystem that includes five native fish species listed as threatened or endangered. A number of factors including sea level rise, seismic activity, continued land subsidence and more extreme climate events will increase the frequency and costs of Delta island failures. Some islands will be deemed too costly to repair and will remain flooded. Flooded Delta islands will vary with their direct and immediate impact on the water quality and ecology of the Delta system. However, with sufficient study, it is possible to manage a flooded island in a way that is more beneficial to the ecosystem. In this study, we use a three-dimensional hydrodynamic and water quality model, SI3DWQ (Doyle 2010), to simulate virtual Delta islands and the surrounding channels. When flooded islands present restoration opportunities, appropriate design and management of the island will be critical to its success as a functional ecosystem component. The objective of this study is to examine the effect of geometric characteristics of flooded islands in the Delta system on productive capacity of the island and to establish the background for scientifically based restoration projects in the Delta. In order to improve the Delta ecosystem, it is desirable to have a flooded island that sustains both a concentration of chlorophyll-a greater than 10 g•L-1 (Muller-Solger 2002) as well as a flux of chlorophyll from the island to the channel. After simulating over 500 model scenarios that investigated variations in breach location, number of breaches, island depth, island size and orientation, it was concluded that it is possible to manage potentially flooded islands in a way to maximize the concentration and flux. However, without careful monitoring and management of future flooded islands, there could be further degradation of the ecosystem.

Doyle, L., W. Fleenor, and G. Schladow (2010). Transport mechanisms in the Stockton Deep Water Ship Channel: a three-dimensional tracer and modeling study. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Since the 1960s, the Stockton Deep Water Ship Channel (DWSC), part of the freshwater tidal reaches of the San Joaquin River, has been periodically subject to critically low concentrations of dissolved oxygen. The problem has been well studied, and researchers agree that there are a number of factors interacting to contribute to the problem, including a change in bathymetry of the system due to the development of the area as a Port, decreased velocity (increased residence time) through the reach, and an increase in oxygen demanding substances from upstream sources. In order to gain a better understanding of the transport processes at work, a sulfur hexafluoride (SF6) tracer study (Schmeider 2008) was conducted during August 2005. The results of the tracer study were incorporated in the calibration of a three-dimensional hydrodynamic and water quality model, SI3DWQ (Doyle 2010), to produce a model capable of exploring how changes in management decisions for the system would impact transport through the channel, and therefore dissolved oxygen concentrations. One of the major findings of the tracer study that was accurately represented in the calibrated model was the tidal trapping of material in the turning basin portion of the DWSC. The tidal trapping allows the turning basin to be an ongoing source of tracer to the rest of the channel. The scenarios investigated helped to alleviate the tidal trapping and decrease the total residence time in the DWSC, which should also alleviate the dissolved oxygen problems.

Drexler, J., C. Alpers, R. Antweiler, C. Fuller, L. Neymark, J. Paces, C. Stricker,

H. Taylor, and L. Windham-Myers (2010). Preliminary results of a paleosalinity model for the Sacramento-San Joaquin Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The extensive marshes in the Sacramento-San Joaquin Delta, which started forming around ~6,700 years ago, are currently freshwater tidal, however, it is unknown whether the salinity regime in the Delta has varied over time between brackish and fresh conditions. This information is important to managers considering major changes to the flow regime in the Delta, because such changes could impact the future sustainability of flora and fauna. The goal of the Rates and Evolution of PEat Accretion through Time Project (REPEAT II) is to reconstruct paleosalinity at several locations in the Delta throughout the last 6000+ years. The approach of REPEAT II is to use geochemical analyses of peat cores to reconstruct Delta paleosalinity through time and space. Preliminary analyses of sodium and strontium concentrations in peat indicate a salinity peak between 1450 CE to 350 BCE at Browns Island and Franks Wetland. In addition, vertical peat profiles of sodium and strontium concentrations show a spatial trend of decreasing salinity from west to east (i.e., Browns Island > Sherman Island > Franks Wetland/Bacon Channel Island). Currently, we are developing a quantitative model of paleosalinity using strontium isotope signatures (87Sr/86Sr) of peat, ocean water, and sediment from the Sacramento and San Joaquin rivers. Application of this model to recent peat is complicated by Gold Rush-derived sediments, which dramatically altered the isotopic and chemical signatures of Sacramento River sediment during the past ~160 years. The next step in developing a salinity model is to determine the 87Sr/86Sr signatures of peat organic matter, peat sediment, and fresh marsh plants to confirm that plants, which ultimately become incorporated into peat, effectively integrate the isotopic signal of the ambient salinity in the Delta.

DuBois, J. (2010). Adult striped bass harvest and survival rate estimates: a forty-year summary and methodology review. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

DuBois, J., E. Gleason, M. Gingras (2010). Review of Juvenile Sturgeon Setline Survey. IEP Newsletter. 23: 9.

Duda, T. F., Jr. (1994). "Genetic population structure of the recently introduced Asian clam, Potamocorbula amurensis, in San Francisco Bay." Marine Biology 119(2): 235-241.
The genetic population structure of the recently introduced Asian clam, Potamocorbula amurensis, in San Francisco Bay was describe using starch gel electrophoresis at eight presumptive loci. Specimens were taken from five environmentally distinct sites located throughout the bay. The population maintains a high degree of genetic variation, with a mean heterozygosity of 0.295, a mean polymorphism of 0.75, and an average of 3.70 alleles per locus. The population is genetically homogeneous, as evidenced from genetic distance values and F-statistics. However, heterogeneity of populations was indicated from a contingency chi-square test. Significant deviations from Hardy-Weinberg equilibrium and heterozygote deficiencies were found at the Lap-1 locus for all populations and at the Lap-2 locus for a single population. High levels of variability could represent a universal characteristic of invading species, the levels of variability in the source population(s), and/or the dynamics of the introduction. Lack of differentiation between subpopulations may be due to the immaturity of the San Francisco Bay population, the "general purpose" phenotype genetic strategy of the species, high rates of gene flow in the population, and/or the selective neutrality of the loci investigated.

Dugdale, R., and A. Marchi (2010). Using climatological anomalies to understand the occurrence of spring blooms in Suisun Bay. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Spring phytoplankton blooms rarely occur in Suisun Bay in spite of high inorganic nutrient concentrations delivered to the Bay by the Sacramento River. Recent research suggests that access to nitrate, the largest pool of dissolved inorganic nitrogen, is a necessary condition for rapid intense blooms to occur in

the northern San Francisco Estuary. However, in Suisun Bay ammonium concentrations are typically too high (at inhibitory levels) to allow access to nitrate by the phytoplankton. Blooms may be initiated when ammonium concentrations fall below 4 M partially relieving this inhibition of nitrate uptake. A further decrease of ammonium concentration to 1 M fully relieves ammonium inhibition resulting in high rates of nitrate uptake and intense chlorophyll accumulation. In the last decade, two large phytoplankton blooms were observed in Suisun Bay (in spring 2000 and spring 2010) with shared features of low ammonium concentrations and low salinity. The reason(s) for the low ammonium concentrations are not clear, although it is known that the source of the ammonium arises from the discharge of sewage effluent upstream in the Sacramento River that may be variable. Within the river some of the introduced ammonium is oxidized to nitrate (nitrification) but little ammonium is used by phytoplankton. To reveal changes related to bloom formation, climatological anomalies of variables from long term data sets for Suisun Bay will be analyzed.

Dugdale, R. C., F. P. Wilkerson, et al. (2007). "The role of ammonium and nitrate in spring bloom development in San Francisco Bay." Estuarine, Coastal, and Shelf Science 73: 17-29.

The substantial inventory of nitrate (NO3) in San Francisco Bay (SFB) is unavailable to the resident phytoplankton most of the year due to the presence of ammonium (NH4) at inhibitory concentrations that prevents NO3 uptake. Low annual primary productivity in this turbid estuary is generally attributed to the poor irradiance conditions. However, this may not be the only cause; spring phytoplankton blooms occur irregularly in north SFB only when NH4 concentrations are low, <4 μmol L−1 and NO3 uptake by phytoplankton occurs. Field measurements and enclosure experiments confirm the NH4 inhibition process to be the cause of low NO3 utilization most of the year. Detailed analysis of spring blooms in three embayments of SFB over 3 years shows a consistent sequence of events that result in bursts of chlorophyll. The first requirement is improved irradiance conditions through stabilization of the water column by stratification or reduced tidal activity. Second, NH4 concentrations must be reduced to a critical range, 1 to 4 μmol L−1 through dilution by precipitation and by phytoplankton uptake. This enables rapid uptake of NO3 and subsequent increase in chlorophyll. The resulting bloom is due to both the initial uptake of NH4 and the subsequent uptake of NO3. The NO3 uptake step is crucial since it is the larger nitrogen source and uptake occurs at higher rates than that for NH4 at the concentrations that occur in SFB. Existing models of light-limited, non-nutrient limited productivity in SFB require modification to include the NH4 inhibition effect. From measured NH4 uptake rates and initial concentrations, calculations can be made to predict the length of time that favorable irradiance conditions are required for the phytoplankton population to reduce ambient NH4 concentrations to non-inhibiting concentrations and allow bloom formation to begin. For Suisun Bay, the time required is so long that blooms are unlikely in any season. For San Pablo and Central Bays, these times are too long in summer but sufficiently short in spring to allow bloom development, depending on the ambient NH4 concentration prior to the productivity season. NH4 sources to SFB are primarily anthropogenic, from agricultural drainage and sewage treatment plants, and if not sufficiently diluted by runoff and precipitation can prevent development of the spring phytoplankton bloom. Attention should be paid to the form of N making up dissolved inorganic nitrogen (DIN) in nutrient-rich estuaries.

Duncan, E., E.L. Hestir, M.J. Santos, and S.L. Ustin (2010). Differences in vegetative morphology of Egeria densa influenced by submerged aquatic vegetation community composition. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Invasive submerged aquatic plant species obstruct waterways, alters Delta Smelt habitat, and hinders fish movement as well as the conveyance of water for drinking and agriculture. In the Sacramento-San Joaquin River Delta Egeria densa is a highly invasive submerged aquatic plant species that decreases biodiversity while acting as an ecosystem engineer. By studying vegetative morphology traits of E. densa growing in either monospecific or mixed patches we can try to understand some aspects of what makes the species particularly invasive. During July and September of 2009, we collected E. densa samples from monospecific and mixed patches and then measured four vegetative morphological traits (number of whorls, intermodal length, number of leaves, biomass). For the month of July, we found that E. densa samples from mixed patches had significantly longer internodal length, fewer whorls per total strand length, and less overall biomass than from monospecific patches. September samples did not show significant differences in morphological features, either in monospecific or mixed patches. Our results suggest that in mixed submerged aquatic vegetation patches E. densa grows faster earlier in the growing season than in monospecific patches; later in the growing season, E. densa growth in monospecific patches allows plants to reach similar morphologies to those in mixed patches. Improved knowledge of how and why this invasive aquatic species spreads rapidly, and which are the crucial phases of its life cycle can improve species-targeted management strategies.

Dunlap, C. E., R. Bouse, and A.R. Flegal (2000). "Past leaded gasoline emissions as a nonpoint source tracer in riparian systems: A study of river inputs to San Francisco Bay." Environmental Science and Technology 34(7): 1211-1215.

Variations in the isotopic composition of lead in 1995–1998 river waters flowing into San Francisco Bay trace the washout of lead deposited in the drainage basin from leaded gasoline combustion. At the confluence of the Sacramento and San Joaquin rivers where they enter the Bay, the isotopic compositions of lead in the waters define a linear trend away from the measured historical compositions of leaded gas in California. The river waters are shifted away from leaded gasoline values and toward an isotopic composition similar to Sierra Nevadan inputs which became the predominant source of sedimentation in San Francisco Bay following the onset of hydraulic gold mining in 1853. Using lead isotopic compositions of hydraulic mine sediments and average leaded gasoline as mixing end members, we calculate that more than 50% of the lead in the present river water originated from leaded gasoline combustion. The strong adsorption of lead (log Kd > 7.4) to particulates appears to limit the flushing of gasoline lead from the drainage basin, and the removal of that lead from the system may have reached an asymptotic limit. Consequently, gasoline lead isotopes should prove to be a useful nonpoint source tracer of the environmental distribution of particle-reactive anthropogenic metals in freshwater systems.

Durand, J., P.B. Moyle, W.A. Bennett, and J. Lund (2010). Historical habitat variability and complexity in the upper San Francisco Estuary. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

High variability in environmental conditions in both space and time once made the upper San Francisco Estuary highly productive for native biota. The original Delta was a vast freshwater marsh interlaced with tidal channels that collected flow from marsh areas through shallow dendritic drainage systems. There was considerable north-south spatial variability created by differences in flow patterns and sediment deposition from the Sacramento and San Joaquin Rivers, as well as east-west variability created by proximity to the inflowing rivers and the more open and salty lower estuary.   Seasonal and annual variation in outflows was created by the natural variability and strong seasonal patterns of precipitation. The rich aquatic system created by this variability contributed to the huge populations of Chinook salmon, Sacramento perch and other fish, large diverse overwintering flocks of waterfowl, and abundant elk and other mammals, as well as dense populations of Native Americans. This physical system has been radically changed by water projects, diking and draining, and other human actions, changes which are irreversible. However, recognizing the conditions under which the native fauna evolved can guide efforts to create habitat favorable for native fish and fowl.

Durand, J., T. O'Rear, and P.B. Moyle (2010). Suisun Marsh in review: trends in environmental Conditions, the food web, and fish abundance. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Suisun Marsh is important habitat for native and alien fishes of the San Francisco Estuary. While few species complete their life cycle in the marsh, it supports large populations of many species by providing both refuge and food. The Suisun Marsh Fish Survey (University of California) has systematically monitored the

marsh's fish populations with otter trawls and beach seines since 1980. The purpose of the study has been to determine environmental factors affecting fish abundance and distribution, especially in relation to water management activities. While general trends in fishes show a slow decline, like much of the estuary, abundance in some key regions of the marsh remain high. These regions contain long, shallow sloughs mostly without functional levees, complex geomorphology and circulating hydrodynamics, which contribute to high residence time. When such areas are allowed to maintain high water quality (free from excessive nitrogen inputs and eutrophication) and are free of destabilizing invasive invertebrates (such as jellyfish and clams), they remain considerably more productive of native fishes than other regions of the estuary. Identifying the factors supportive of fish habitat in the marsh can guide restoration throughout the estuary, and help to anticipate future changes in climate, sea level and water operations.

Durieux, E., R. Connon, et al. (2012). "Cytochrome P4501A mRNA and protein induction in striped bass (<i>Morone saxatilis</i>)." Fish Physiology and Biochemistry 38(4): 1107-1116.

Durieux, E., T. Farver, et al. (2011). "Natural factors to consider when using acetylcholinesterase activity as neurotoxicity biomarker in Young-Of-Year striped bass (Morone saxatilis)." Fish Physiology and Biochemistry 37(1): 21-29.

Earle, C. J. (1993). "Asynchronous droughts in California streamflow as reconstructed from tree rings." Quaternary Research (Orlando) 39(3): 290-299.
Streamflow since 1560 A.D. for four rivers within the Sacramento River Basin, California, has been reconstructed dendroclimatically. Both the highest and the lowest reconstructed streamflows occurred during the historical period, with high flows from 1854 to 1916 and low flows from 1917 to 1950. Prolonged (decade-scale) excursions from the mean have been the norm throughout the reconstructed period. The periods of high and low streamflow in the Sacramento Basin are generally synchronous with wet and dry periods reconstructed by dendroclimatic studies in the western United States. The record indicates a number of asynchronous droughts or wet years. The strongest contrasts are developed between northern (western Washington and Oregon or the Columbia Basin) and southern (the Sacramento Basin or central California) climate regions. These asynchronous events may be due to variation in the latitude of the subtropical high and in the latitudinal position of winter storms coming off the Pacific. No association was found with El Niño-Southern Oscillation events.

Eckard, R., T. Kraus, P.J. Hernes, and B.A. Bergamaschi (2010). Fatty acid production and decomposition in the State Water Project. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The Delta-derived water that flows through the State Water Project (SWP) is characterized by frequent high levels of disinfection by-product (DBP) forming materials. Following municipal water treatment, DBP concentrations contained in Delta-derived water can exceed regulated maximum contaminant levels (MCLs) for drinking water, resulting in increased health risk to consumers. Components of the dissolved organic carbon (DOC) contained in SWP waters are understood to be the primary source of DBP forming materials in the SWP system. But what is the original source of DBP precursors? High Delta DOC concentrations are commonly thought to be transported through the SWP to municipal treatment plants, where DBP formation occurs. Given the weeks-to-months of residence time that Delta water spends in the SWP, combined with reservoir algae blooms, photoxidation, and other degradation processes, it is reasonable to question the potential role of DOC production and degradation in the SWP that could result in in-situ production of DBP precursors. This study examines DOC production and degradation trends that occur in the SWP system. The fatty acid component of SWP DOC is tracked from the Delta through the SWP and major reservoirs, to help resolve and quantify the extent of potential sites or periods for DBP precursor production in the SWP. Study results will also help to constrain locational and temporal patterns of DOC degradation in the SWP, and will help inform water managers regarding the extent to which mitigation efforts and best management practices for DBP precursor control should be implemented in the Delta

versus SWP facilities.

Edmunds, J. L., K. M. Kuivila, et al. (1999). Do herbicides impair phytoplankton primary production in the Sacramento-San Joaquin River Delta? U.S. Geological Survey Toxic Substances Hydrology Program, Charleston, South Carolina, March 8-12, 1999.

Eldridge, M. B., J. A. Whipple, et al. (1982). "Bioenergetics and growth of striped bass, Morone saxatilis, embryos and larvae." Fishery Bulletin 80: 461-474.
Fluctuations in year class size of striped bass (M. saxatilis) are known to be related to development and survival in the early life stages. Bioenergetic aspects of growth and development of striped bass embryos and larvae were determined in the laboratory to discover some of the physiological needs and processes of these stages from fertilization to metamorphosis. Energy was provided by endogenous (yolk and oil globule) and exogenous (Artemia sp.) sources. Daily food rations of larvae from the onset of feeding to metamorphosis were estimated for field and laboratory conditions. Rations increased with size and age of the larvae. Wild larvae were estimated to have daily rations substantially greater than those of cultured larvae. Energy outputs were measured in growth and oxygen consumption. Embryos and prefeeding larvae had the highest Q sub(O2), while metabolism on a weight-specific basis increased with tissue dry weight and was best described by a power function. Gross caloric conversion efficiencies were highest from fertilization to initial feeding. In an energy budget model, striped bass embryos and larvae given the highest food density consumed yolk energy at constant rates until totally absorbed. Metabolism fluctuated according to developmental stage.

Emmett, R., R. Lianso, et al. (2000). "Geographic signatures of North American west coast estuaries." Estuaries 23(6): 765-792.
West Coast estuaries are geologically young and composed of a variety of geomorphological types. These estuaries range from large fjords to shallow lagoons; from large to low freshwater flows. Natural hazards include El Ninos, strong Pacific storms, and active tectonic activity. West Coast estuaries support a wide range of living resources: five salmon species, harvestable shellfish, waterfowl and marine birds, marine mammals, and a variety of algae and plants. Although populations of many of these living resources have declined (salmonids), others have increased (marine mammals). West Coast estuaries are also centers of commerce and increasingly large shipping traffic. The West Coast human population is rising faster than most other areas of the U.S. and Canada, and is distributed heavily in southern California, the San Francisco Bay area, around Puget Sound, and the Fraser River estuary. While water pollution is a problem in many of the urbanized estuaries, most estuaries do not suffer from poor water quality. Primary estuarine problems include habitat alterations, degradation, and loss; diverted freshwater flows; marine sediment contamination; and exotic species introductions. The growing West Coast economy and population are in part related to the quality of life, which is dependent on the use and enjoyment of abundant coastal natural resources.

Emmett, R. L., S. L. Stone, et al. (1991). Distribution and abundance of fishes and invertebrates in west coast estuaries, Volume II: species life history summaries. Rockville MD, NOAA/NOS Strategic Environmental Assessments Division.
The report is the second of two volumes that present information on the spatial and temporal distributions, relative abundance, and life history characteristics of 47 fish and invertebrate species in 32 estuaries along the contiguous west coast of the U.S. Information presented in the volume focuses on species life history summaries which were written to identify the critical life history characteristics that help define a species' occurrence in estuaries. The life history summaries are not a complete treatise on each species; however they provide a concise account of the most important physical and biological factors known to influence a species' occurrence.

Engle, D., and G. Lau (2010). Does ammonia exceed toxicity thresholds in the upper San Francisco Estuary? A Ccmparison of ambient data and toxicity thresholds from 1974-2010. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Engle, D. (2010). How well do we understand the feeding ecology of estuarine mesozooplankton? A survey of the direct evidence. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Over the last three decades, a shift in phytoplankton composition has been observed in the upper San Francisco Estuary (the brackish and freshwater Delta) characterized by a decline in the relative abundance of diatoms, especially centric diatoms belonging to the order Thalassiosirales, and an increase in other taxa including flagellates, green algae, and cyanobacteria. A central assumption underlying recent food-web-based hypotheses for the recent decline in several pelagic fish species (the Pelagic Organism Decline, or POD) is that these changes in phytoplankton composition signal a deterioration in the quality of food for estuarine mesozooplankton, and calanoid copepods in particular, that may have repercussions for organisms at higher trophic levels. Direct evidence of feeding preferences of mesozooplankton from the San Francisco Estuary is provided by a few studies of gut contents and feeding trials which indicate that the trophic status of copepods in the estuary is complex and that motile food sources (including heterotrophic cilliates) and non-diatom phytoplankton are potentially well-utilized by ecologically important zooplankton taxa. In this study, the status of our knowledge regarding the feeding behavior of copepods and other key zooplankton taxa is evaluated using an extensive survey of published literature and pertinent unpublished studies from the San Francisco Estuary and other systems. Evidence from feeding trials and gut analyses of field caught zooplankton are compared, and data gaps identified. The availability of information regarding the nutritional value of heterotrophic and autotrophic food resources for pertinent zooplankton taxa is described.

Enright, C. (2010). Hydrodynamics and transport processes on the historical landscape: geomorphic control of functional complexity and implications for restoration. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Native fishes and food webs in the Bay-Delta evolved largely in response to the morphology of the historical landscape. Processes like sedimentation, tidal dynamics, and water temperature regulation are mediated by the particular morphology of bays, channels, sloughs, and marsh plains. In turn, morphology is influenced by tidal action, vegetation, and soil dynamics. Ecosystem functions and services that support nekton depend on both the productive capacity of, and access to, morphological attributes that support food, refuge, and ontogeny options. This talk will examine the historical and modern Delta planform and propose that historical landscape scales, as perceived by nekton, are in some ways much larger, and in other ways much smaller, than the modern Delta. The straightened and widened, and cut-across channels of the modern delta tend to preserve tidal energy and produce efficient mixing of scalar gradients and residence time, while at the same time reducing the distance between any two points. The functional outcome of the channelized modern Delta is that the distance to different environmental conditions is generally much larger than in the historical Delta. A combination of data, modeling, and graphical evidence will be presented to show that modern Delta channel connectivity is high, yet access to ecotonal gradients and associated habitat options is severely limited. Given this hyper-degraded state, Delta ecosystem restoration designs must consider the wetland-to-channel “connectivity rate” to optimize both the capacity to produce ecosystem services, and access to those services by both marsh and channel preferring organisms.

Enright, C., Steven D. Culberson, and Jon R. Burau (2013). "Broad Timescale Forcing and Geomorphic Mediation of Tidal Marsh Flow and Temperature Dynamics." Estuaries and Coasts May 2013(May 2013): 29.

Tidal marsh functions are driven by interactions between tides, landscape morphology, and emergent vegetation. Less often considered are the diurnal pattern of tide extremes and seasonal variation of solar insolation in the mix of tidal marsh driver interactions. This work demonstrates how high-frequency hydroperiod and water temperature variability emerges from disparate timescale interactions between tidal marsh morphology, tidal harmonics, and meteorology in the San Francisco Estuary. We compare the tidal and residual flow and temperature response of

neighboring tidal sloughs, one possessing natural tidal marsh morphology, and one that is modified for water control. We show that the natural tidal marsh is tuned to lunar phase and produces tidal and fortnight water temperature variability through interacting tide, meteorology, and geomorphic linkages. In contrast, temperature variability is dampened in the modified slough where overbank marsh plain connection is severed by levees. Despite geomorphic differences, a key finding is that both sloughs are heat sinks in summer by latent heat flux-driven residual upstream water advection and sensible and long-wave heat transfer. The precession of a 335-year tidal harmonic assures that these dynamics will shift in the future. Water temperature regulation appears to be a key function of natural tidal sloughs that depends critically on geomorphic mediation. We investigate approaches to untangling the relative influence of sun versus tide on residual water and temperature transport as a function of system morphology. The findings of this study likely have ecological consequences and suggest physical process metrics for tidal marsh restoration performance.

Escobar-Arias, M., D. Purkey, and P. Moyle (2010). Climate change and spring-run Chinook salmon in California: Scenario analysis of flow and temperature changes for Butte Creek, California. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Spring-run Chinook salmon (Oncorhynchus tshawytscha) would be particularly vulnerable to climate change because adults hold in freshwater for the summer before spawning in the autumn. Our objective was to determine the streamflow and temperature thresholds that would lead to long-term losses in spring-run Chinook salmon in Butte Creek, a stream in the northern Sierra Nevada of California. Our hypotheses were that (1) climate induced changes in flow and temperature will lead to critical reductions in the available habitat of spring-run Chinook salmon, and (2) the loss/reduction of salmon will reduce the diversity and abundance of biota in the riparian corridor. We used WEAP21, an integrated watershed hydrology, water management, and water quality model to simulate potential changes in flow and temperature in response to climate change in Butte Creek, focusing on the critical summer months. WEAP21 outputs were used to drive SALMOD (USGS), a spatially explicit, size/stage structured population dynamics model that predicts the growth, survival, and movement of salmon in freshwater systems. An expert panel was convened to assess impacts on wildlife resulting from changes to the salmon marine-derived nutrient subsidy. We used bias-corrected and spatially downscaled greenhouse gas emission scenarios A2 and B1 for the period 2010 – 2099 for the six global circulation models (GCMs) recommended by the California Climate Change Research Center. Preliminary scenario analysis of summer months for the periods 2010-2031, 2034-2064, and 2064-2099, using WEAP21 outputs indicate a reduction of streamflow in the ranges of 6-30, 13-32 and 33-45%, and an increase in water temperature in the ranges of 1-2.8, 1.5-3.5 and 2-5.7 oC, respectively, relative to the historical period 1986-2005. We used WEAP21 and SALMOD to evaluate potential management options to ameliorate these impacts. Predicted responses of spring-run Chinook salmon and the riparian biota will be presented in additional presentations in this session.

Esterly, C. O. (1924). The free-swimming copepoda of San Francisco Bay. University of California Pubolications in Zoology. Berkeley, University of California: 26:81-129.

Evens, J. G., G. W. Page, et al. (1991). "Distribution, relative abundance and status of the California black rail in western North America." Condor 93(4): 952-966.

We conducted breeding season surveys of California Black Rail (Laterallus jamaicensis coturniculus) populations in California and western Arizona from 1986-1989. During the course of our field work we developed a method to derive abundance indices and assign abundance values to each study area. We found the bulk of the population (>80%) confined to the northern reaches of the San Francisco Bay estuary, especially the tidal marshland of San Pablo Bay and associated rivers. Elsewhere, distribution was patchy and subpopulations were small and isolated. Through a review of the literature, discussions with local field ornithologists, and our field work, we determined that the Black Rail population in Western North America is suffering a progressive decline. The causes of this downward trend--all

related to habitat loss or degradation--are pervasive and ongoing.

Fairey, R., K. Taberski, et al. (1997). "Organochlorines and other environmental contaminants in muscle tissues of sportfish collected from San Francisco Bay." Marine Pollution Bulletin 34(12): 1058-1071.
Edible fish species were collected from 13 locations throughout San Francisco Bay, during the spring of 1994, for determination of contaminant levels in muscle tissue. Species collected included white croaker, surfperch, leopard and brown smoothhound sharks, striped bass, white sturgeon and halibut. 66 composite tissue samples were analysed for the presence of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, trace elements and dioxin/furans. The US EPA approach to assessing chemical contaminant data for fish tissue consumption was used for identifying the primary chemicals of concern. Six chemicals or chemical groups were found to exceed screening values (SVs) established using the US EPA approach. PCBs (as total Aroclors) exceeded the screening level of 3 ng g super(-1) in all 66 muscle tissue samples, with the greatest concentrations (638 ng g super(-1)) found near San Francisco's industrial areas. Mercury was elevated (>0.14 mu g g super(-1)) in 40 of 66 samples with the greatest concentrations (1.26 mu g g super(-1)) occurring in shark muscle tissues. Concentrations of the organochlorine pesticides dieldrin, total chlordane and total dichlorodiphenyltrichloroethane (DDT) exceeded screening levels in a number of samples. Dioxin/furans (as toxic equivalent concentrations (TEQ's)) were elevated (>0.15 pg g super(-1)) in 16 of the 19 samples analysed. Fish with high lipid content (croaker and surfperch) in their muscle tissue generally exhibited higher organic contaminant levels while fish with low lipid levels (halibut and shark) exhibited lower organic contaminant levels. Tissue samples taken from North Bay stations most often exhibited high levels of chemical contamination. The California Office of Health Hazard Assessment is currently evaluating the results of this study and has issued an interim Health Advisory concerning the human consumption of fish tissue from San Francisco Bay.

Fancett, M. S., and W.J. Kimmerer (1985). "Vertical migration of the demersal copepod Pseudodiaptomus as a means of predator avoidance." The Journal of Experimental Marine Biology 88: 31-43.
We tested the hypothesis that mortality due to visual predation is reduced by vertical migration of the demersal copepod Pseudodiaptomus (P. cornutus Nicholls and P. colefaxi Bayly) in Westernport Bay, Australia. Late copepodites and adults of Pseudodiaptomus remain near the bottom by day, rising into the water column at night or on cloudy days. Vertical migration was most pronounced in ovigerous females while early copepodites did not migrate. In aquarium experiments, the yellow-eye mullet, Aldrichetta forsten (Cuvier & Valenciennes), a common visual planktivore, preyed most heavily on ovigerous female Pseudodiaptomus and least on early copepodites. Furthermore, predation was heavier on adults of Pseudodiaptomus than on those of Acartia tranteri, Bradford an abundant copepod that is not demersal. Pseudodiaptomus does not feed while on the bottom by day, although its feeding is not inhibited by light. The rate of egg production by Pseudodiaptomus with a continuous food supply was not different from that of females given an intermittent supply. In contrast, egg production by Acartia tranteri was significantly lower with a discontinuous supply of food than with a continuous supply. This apparently relates to lipid storage, since the proportion of lipid in dry wt of Pseudodiaptomus females was 32 ± 9% compared to 17 ± 2% for Acartia tranteri. The demersal behaviour of Pseudodiaptomus therefore imposes no penalty, and is a suitable way of avoiding visual predators.

Fazel, K. (2010). Coastal Upwelling and Sea Surface Temperature, Water Years 2008 and 2009. IEP Newsletter. 23: 3.

Feinstein, L. (2010). Cryptic Spartina alterniflora x S. foliosa hybrids: the challenge of eradicating invasive hybrids in a widespread native plant population. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Spartina alterniflora x S. foliosa, the hybrid of native Spartina foliosa and introduced Spartina alterniflora, is a highly invasive weed in San Francisco Bay

salt marshes. Government agencies have funded eradication efforts since the year 2000. The control program herbicides hybrids that are visually distinct from native Spartina, and occasionally uses genetic testing on plants of questionable heritage. Management has drastically reduced the area occupied by morphologically evident hybrids. However, it is possible that exotic alleles persist in morphologically cryptic hybrids that resemble native plants. To investigate the existence of cryptic hybrids, I genotyped 92 plants in four marshes using ten microsatellite and seven RAPD markers. Samples were also measured for six morphological features. I classified the hybrids into visually evident and cryptic hybrids, where cryptic hybrids were those individuals that could not be differentiated from natives in a multivariate model of their morphological traits. 25% of tillers tested were hybrids. 78% of hybrids were cryptic, and among these, an average of 29% of their alleles derived from exotic S. alterniflora, compared to 55% in evident hybrids. MANOVA showed a significant relationship between the percent of S. alterniflora alleles and morphology: plants with a high percent of exotic markers deviate further from the native phenotype. My work suggests that highly introgressed, morphologically cryptic hybrids may act as a reservoir of hybrid alleles that are able to escape detection by the control program. Resampling in 2010 will show if artificial selection for a cryptic morphology is driving an increase in cryptic hybrids. A common garden experiment is underway to test for the ecological differences between native Spartina, cryptic hybrids, and evident hybrids; early results indicate that cryptic hybrids as well as evident hybrids can survive across a broader intertidal range than native Spartina, which could disrupt the functioning of valuable marsh habitat.

Ferrari, F. D., and J. Orsi. (1984). "Oithona davisae, new species, and Limnoithona sinensis (Burckhardt, 1912) (Copepoda: Oithonidae) from the Sacramento-San Joaquin Estuary, California." Journal of Crustacean Biology 4(1): 106-126.

Zooplankton samples from the Sacramento-San Joaquin Estuary collected by the California Department of Fish and Game and the United States Geological Survey were examined for cyclopoid copepods of the family Oithonidae. Of the three species found, Limnoithona sinensis, Oithona davisae, new species, and O. similis, the first two are described here. Limnoithona sinensis, like its congener L. tetraspina, has been previously reported from delta localities in the Yangtze River, China. In general morphology O. davisae is similar to many estuarine/lagoonal oithonids of temperate and tropical American coastal waters. Two characters, an elongate ventrally pointed rostrum and/or a long distal spine on the inner lobe of the first maxilla, suggest affinities to the Indo-West Pacific estuarine species O. brevicornis, O. aruensis, and O. wellershausi. In the northern hemisphere O. similis is a common subarctic oceanic species. Specimens have also been reported from estuarine areas. Zooplankton samples taken in coastal estuarine localities from Humboldt Bay south to Baja California were examined to determine the distribution of these three species. O. similis was the only species found.

Ferrari, M. C. O., L. Ranaker, K.L. Weinersmith, M.J. Young, A. Sih, J.L. Conrad (2013). "Effects of turbidity and an invasive waterweed on predation by introduced largemouth bass." Environmental Biology of Fishes.

Anthropogenic activities lead to changes in characteristics of aquatic ecosystems, including alteration of turbidity and addition of invasive species. In this study, we tested how changes in turbidity and the recent invasion of an aquatic macrophyte, Egeria densa, may have changed the predation pressure by introduced largemouth bass on juvenile striped bass and delta smelt, two species that have seen a drastic decline in recent decades in the Sacramento-San Joaquin Delta. In a series of mesocosm experiments, we showed that increases in vegetation density decreased the predation success of largemouth bass. When placed in an environment with both open water and vegetated areas, and given a choice to forage on prey associated with either of these habitats, largemouth bass preyed mainly on open water species as opposed to vegetation-associated species, such as juvenile largemouth bass, bluegill or red swamp crayfish. Finally, we showed that turbidity served as cover to open water species and increased the survival of delta smelt, an endemic species at risk. We also found that such open water prey tend not to seek refuge in the vegetation cover, even in the presence of an imminent predation threat. These results provide the beginning of a mechanistic framework to explain how decreases in turbidity and

increases in vegetation cover correlate with a decline of open water species in the Sacramento-San Joaquin Delta.

Ferraro, S. P. and F. A. Cole (1997). "Effects of DDT sediment-contamination on macrofaunal community structure and composition in San Francisco Bay." Marine Biology 130(2): 323-334.
The objectives of this study were to determine the effects of sediment contamination on the benthic macrofauna and to predict macrofaunal changes following remediation at a Superfund (uncontrolled hazardous waste) site in San Francisco Bay, California, USA. DDT and its metabolites (capital sigma DDT) were the contaminants of concern. With few small-scale exceptions, all (>100) other sediment contaminants ever measured at the site were present at background or non-toxic levels. In hierarchical regressions [Y=f(X sub(1), X sub(2), X sub(3)), where X sub(1)=sediment %silt + clay, X sub(2)=sediment total organic carbon (OC), and X sub(3)=log10 (capital sigma DDT mu g/g OC)] with data from samples collected at the study site, log sub(10) (capital sigma DDT mu g/g OC) explained a highly significant amount of the variance in the infaunal index (II) and log sub(10) (number of Amphipoda excluding Grandidierella japonica + 1) after statistically controlling for the potential effects of sediment

Ferreira, I. C., S. K. Tanaka, et al. (2005). "Musings on a model: CalSim II in California's water community." San Francisco Estuary and Watershed Science 3(1): [vp].
Computer model results are becoming more prominent in water policy deliberations in California. CalSim II is the most prominent water management model in California, and has become central to a variety of water management and policy issues and controversies. This paper reports on the results of an extensive set of loosely-structured interviews with members of California's technical and policy-oriented water management community regarding the use and development of CalSim II in California. The interviewers reflect on the thoughts of interviewees and how such interview activities can further policy-effective modeling and technical activities for water management. CalSim II is a complex model of a complex part of California's changing multi-purpose water system. As such, analytical controversies and misunderstandings are inevitable. Ideally, a model and its associated data would perform an additional service as a forum to resolve technical controversies and continually improve quantitative understanding of the system. While CalSim II is generally seen as a significant improvement over previous models, a wide variety of ideas are suggested for improvements.

Feyrer, F., and R. Baxter. (1998). "Splittail fecundity and egg size." California Fish and Game 84(3): 119-126.
Fecundity and egg size of splittail, Pogonichthys macrolepidotus, are described from 17 specimens collected from February to April 1996. Splittail included in the study ranged from 216 to 328 mm standard length and were sampled from a broad area of their distribution. Ovaries accounted for a mean of 13.2% of total body weight. Splittail length accounted for nearly 40% of the variation in gonadosomatic index. Mean egg diameter was 1.2 mm and ranged from 1.0 to 1.5 mm. Egg size and splittail length were not related. Fecundity ranged from 28,416 to 168,196 ova. Mean relative fecundities were 261 ova/mm standard length and 163 ova/g total weight. One earlier study found slightly lower estimated fecundity, whereas another estimated fecundity to be significantly higher.

Feyrer, F., and S. Matern (2000). Changes in fish diets in the San Francisco Estuary following the invasion of the clam Potamocorbula amurensis. IEP Newsletter. 13: 21-26.

Feyrer, F., and L. Rivard (2001). "Categorized bibliography of the delta smelt, Hypomesus transpacificus, 2nd edition." Interagency Ecological Program for the San Francisco Estuary.
The delta smelt bibliography contains 178 references (the first edition in 1998 contained 102). To increase comprehensiveness, non primary literature (gray literature, newsletter articles, memos, etc.) has been included. References have been placed into eight applicable categories (see page 2) to help readers find

information on specific subjects. Most of the references in the bibliography are readily available at major libraries. Gray literature associated with the IEP can be obtained from the California Department of Water Resources, Environmental Services Office, Sacramento CA, or the California Department of Fish and Game, Central Valley Bay-Delta Branch, Stockton CA. A list of delta smelt resources available on the internet occurs on the last page.

Feyrer, F. (2001). Fish assemblage structure and environmental associations in the southern Sacramento-San Joaquin Delta. IEP Newsletter. 14: 42-45.

Feyrer, F., G. O'Leary, T.R. Sommer, and W. Harrell (2001). Preliminary validation of daily otolith increments in juvenile splittail. IEP Newsletter. 14: 15.

Feyrer, F., B. Herbold, S.A. Matern, and P.B. Moyle (2003). "Dietary shifts in a stressed fish assemblage: Consequences of a bivalve invasion in the San Francisco Estuary." Environmental Biology of Fishes 67(3): 277-288.
We compared dietary patterns within a temperate estuarine fish assemblage (Suisun Marsh, CA, U.S.A.) during a period of high mysid shrimp abundance and after a major decline in mysid abundance caused by the invasion of the overbite clam Potamocorbula amurensis. Prior to the invasion, high dietary overlap, high stomach fullness, and low niche breadth occurred among the fishes in spring when mysid populations were high. Dietary overlaps decreased and niche breadth increased for all species but the endemic splittail Pogonichthys macrolepidotus in fall when mysid populations were low. Eight native species exhibited lower overall collective overlaps and fuller stomachs than five alien species, suggesting more efficient resource partitioning. After mysid abundance declined, only alien striped bass Morone saxatilis preyed upon mysids in greater than trace amounts. An alien mysid became an important prey for small striped bass, but striped bass also switched to piscivory at a smaller size than when mysids were abundant. Eight of 13 species exhibited significant declines in abundance during the study period, which were concordant with the original importance of mysids in their diets. Our results suggest that altered lower food web dynamics in the San Francisco Estuary caused by the invasion of the overbite clam changed fish diets and have contributed to declines in fish abundance.

Feyrer, F., and M. Healey (2003). "Fish community structure and environmental correlates in the highly altered southern Sacramento-San Joaquin Delta." Environmental Biology of Fishes 66(2): 123-132.
We sampled 11 sites in the southern Sacramento-San Joaquin Delta from 1992–1999, to characterize fish communities and their associations with environmental variables. Riparian habitats were dominated by rock reinforced levees, and large water diversion facilities greatly influenced local hydrodynamics and water quality. We captured 33 different taxa, only eight of which were native. None of the native species represented more than 0.5% of the total number of individuals collected. The abundance of native species was consistently low but typically peaked during high outflow periods. Fish communities were predominantly structured along environmental gradients of water temperature and river flow. Native species (tule perch, Hysterocarpus traski, & Sacramento sucker, Catostomus occidentalis) were associated with conditions of high river flow and turbidity, while the majority of the non-native species were associated with either warm water temperature or low river flow conditions. The exceptions were the non-native striped bass, Morone saxatilis, and white catfish, Ameiurus catus, which were positively associated with relatively high river flow. Variation in fish community structure was greater among river locations within years than within river locations among years, thus fish communities at each river location were consistently different each year. Differences in fish communities among river locations were correlated with river flow and turbidity. We predict that the fish communities of this region will remain numerically dominated by non native species if the environmental conditions we observed persist in the future.

Feyrer, F., L.R Brown, R.L Brown, and J.J Orsi, Ed. (2004). Early Life History of Fishes in the San Francisco Estuary and Watershed. Bethesda, American Fisheries Society.

This book is the primary source of information on the early life history of fishes in the San Francisco Estuary and its watershed. There has been a large body of research and monitoring conducted in the system; however, very little of it has been published. This book contains more papers on fish early life history in the system than all previous publications combined. There is a great deal of interest in the system itself, as it is the largest estuary on the Pacific Coast of the United States. In addition to providing a resource for people generally interested in the system, original papers on feeding ecology, growth, environmental requirements of species, community ecology, emerging modeling techniques, development, and toxicology will benefit scientists specializing in a variety of disciplines.

Feyrer, F. (2004). Ecological segregation of native and alien larval fish assemblages in the southern Sacramento-San Joaquin Delta. Early life history of fishes in the San Francisco Estuary and watershed. F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi. Bethesda, Maryland, American Fisheries Society. Symposium 39: 67-79

Fish larvae were sampled at multiple fixed sites from late winter to early summer over 6 years (1990–1995) in the southern Sacramento–San Joaquin Delta. A total of 394,797 fish larvae representing 15 species or taxonomic groups was collected. The assemblage was numerically dominated by three species that represented 98% of the total catch: alien shimofuri goby Tridentiger bifasciatus (71%), threadfin shad Dorosomapetenense (15%), and native prickly sculpin Cottus asper (12%). The abundance of native and alien species differentially clustered along environmental gradients of water temperature and river flow. Each native species (prickly sculpin, splittail Pogonichthys macrolepidotus, delta smelt Hypomesus transpacificus, longfin smelt Spirinchus thaleichthys, and Sacramento sucker Catostomus occidentalis) and one alien species (bigscale logperch Percina macrolepida) were associated with the early season conditions of cool water temperature and high river flow. Alien species (especially shimofuri goby, threadfin shad, and ictalurid catfishes) were associated with late season conditions of relatively warm water temperature and low river flow. Accordingly, native species dominated the assemblage February–March, while alien species dominated May–July. However, peak seasonal abundance of alien species was typically five times greater than that of native species. Seasonal succession of assemblage structure was persistent among years and was highly correlated with water temperature, a likely result of the differential spawning requirements of adult fishes. Interannually, the assemblage remained consistent over the study period despite considerable variability in delta inflow. I hypothesize, given the consistent temporal segregation between native and alien larval fish assemblages, that direct interactions such as competition between the two groups may not be a major factor influencing poor native fish recruitment in the south delta.

Feyrer, F., T.R Sommer, S.C. Zeug, G. O'Leary, and W. Harrell (2004). "Fish assemblages of perennial floodplain ponds of the Sacramento River, California (USA), with implications for the conservation of natives fishes." Fisheries Management and Ecology 11(5): 335-344.

To assess the likelihood of enhancing native fish populations by means of floodplain restoration projects, habitat characteristics and fish assemblages of seven perennial floodplain ponds in Yolo Bypass, the primary floodplain of the Sacramento River, California (USA), were examined during summer 2001. Although all ponds were eutrophic, based upon high chlorophyll a or dissolved nutrient concentrations, relatively large shallow ponds generally exhibited higher specific conductivity and dissolved phosphorus concentrations than small deep ponds, which exhibited greater water transparency and total dissolved nitrogen concentrations. Using multiple gear types, 13 688 fishes comprising 23 species were collected. All ponds were dominated by alien fishes; only three native species contributing <1% of the total number of individuals and <3% of overall biomass were captured. Fish assemblage structure varied among ponds, notably between engineered vs. natural ponds, and was related to specific conductance, total dissolved solids and water transparency.

Feyrer, F. (2004). Length-weight relationships and conversions for fresh and ethanol-preserved age-0 splittail. IEP Newsletter. 17: 10.

Feyrer, F., T.R. Sommer, J. Hobbs, and B. Bridges (2004). Otolith ageing of age-0 splittail: techniques, validations, and limitations. IEP Newsletter. 17: 24-27.

Feyrer, F., T.R. Sommer, and R. Baxter (2005). "Spatial-temporal distribution and habitat associations of age-0 splittail in the lower San Francisco Estuary Watershed." Copeia 2005(1): 159-168.

The Splittail (Pogonichthys macrolepidotus) is a cyprinid endemic to the San Francisco Estuary and its lower watershed. Although it was recently removed from the Federal Endangered Species Act list of threatened species, it is still a species of concern because of uncertainties regarding its abundance and distribution. Because little information is available on early life stages for which to base management decisions, we examined historical long-term monitoring data and conducted a field study in 2002 and 2003 to examine the distribution and habitat associations of age-0 Splittail. During winter and spring, adults migrate from the upper San Francisco Estuary and the Sacramento-San Joaquin Delta upstream into freshwater tributaries and floodplains to spawn. Although previous work suggested a decreasing upstream range for this species, we found that catch data for age-0 Splittail (≤ 50 mm fork length) during a monitoring program spanning 28 years (1976–2003) indicated the upstream-most distribution in the Sacramento River has remained persistent at 232–296 km upstream from the estuary. Additionally, centers of distribution in the Sacramento and San Joaquin Rivers varied according to hydrology; distance upstream was similar in years of high and intermediate river flows, but increased during low flow years. In all years, age-0 Splittail became abundant in April or May and by June and July had a center of distribution downstream at the margin of the Sacramento-San Joaquin Delta. Our field study showed that in addition to these two primary tributaries, substantial spawning also occurred in other smaller tributaries with previously uncertain importance to Splittail production, namely the Petaluma River, Napa River, and Butte Slough. We also found that age-0 Splittail favor low velocity shallow-water habitats. Compared to main channel habitats, age-0 Splittail were 6.5 times more common in backwaters in upstream riverine locations, and 3.5 times more common in offchannel intertidal habitats in downstream tidal locations. Our study demonstrates the distribution of Splittail is more widespread than previously believed and underscores the importance of offchannel habitats as nursery areas for age-0 fish

Feyrer, F., T.R. Sommer, and W. Harrell (2006). "Importance of flood dynamics versus intrinsic physical habitat in structuring fish communities: evidence from two adjacent engineered floodplains on the Sacramento River, California." North American Journal of Fisheries Management 26(2): 408-417.

We examined the factors structuring fish communities at two adjacent engineered floodplain systems on the Sacramento River, California: Yolo and Sutter bypasses. We intensively sampled fishes at each location during January–June 2002 and 2004 by rotary screw trap, collecting a total of 126,635 fish comprised of 29 species. Nonmetric multidimensional scaling indicated that distinct fish communities persisted between the locations during our study, despite nearly identical hydrographs and water temperature regimes. Regression models evaluated with an information-theoretic approach also indicated that location was an important factor explaining the abundances of selected species. Overall, Yolo Bypass had more species and a greater proportion of native species than did Sutter Bypass. Sutter Bypass had a greater proportion of species classified as freshwater, while Yolo Bypass had a greater proportion of species classified as either estuarine or anadromous. We believe these results are related to substantial differences in the underlying physical habitat within the floodplains, which are primarily associated with connectivity to the adjacent river. Although the dynamic flooding that occurs at both locations appeared unable to override the underlying physical habitat differences in structuring the overall fish communities, it was important in controlling the abundances of two prominent native species, Chinook salmon Oncorhynchus tshawytscha and splittail Pogonichthys macrolepidotus, which represented 79% of all individuals collected; splittails spawn on the inundated floodplains, and age-0 individuals of both species use these areas as rearing habitat. Our results have important restoration implications in that they illustrate the importance of both flood pulse dynamics and underlying physical habitat associated with connectivity in structuring river–floodplain fish communities.

Feyrer, F., T.R. Sommer, and W. Harrell (2006). "Managing floodplain inundation for native fish: production dynamics of age-0 splittail in California's Yolo Bypass." Hydrobiologia 573: 213-226.

We used data gathered across seven hydrologically diverse years (1998–2004) from Yolo Bypass, the primary floodplain of the Sacramento River, California (U.S.A.), to examine how physical and hydrological characteristics of floodplain habitat influence spawning and patterns of occurrence and production of age-0 splittail (Pogonichthys macrolepidotus). We estimated that spawning in Yolo Bypass occurred from January to May but typically peaked in March in close association with the vernal equinox. Production of age-0 splittail varied significantly among years. Using an information-theoretic approach to evaluate several factors, the amount of inundated floodplain habitat available during the primary spawning and rearing period of January–June was the most important factor we examined in explaining annual production (81% of variance explained in a linear regression model). Peak emigration of age-0 splittail from Yolo Bypass varied temporally among years but always occurred when fish were 30–40 mm in length, suggesting an ontogenetic influence on floodplain emigration. Annual system-wide production of age-0 splittail derived from a separate long-term monitoring program exhibited an apparent positive relationship with annual production in Yolo Bypass, suggesting that site-specific floodplain-derived production within Yolo Bypass may be important at a regional scale. Our results support the flood pulse concept for cyprinids in regulated temperate river–floodplain systems and demonstrate floodplain inundation in regulated systems can be managed to benefit native fish.

Feyrer, F., T.R. Sommer, and J. Hobbs (2007). "Living in a dynamic environment: variability in life history traits of age-0 splittail in tributaries of San Francisco Bay." Transactions of the American Fisheries Society 136: 1393-1405.

Splittail Pogonichthys macrolepidotus is a relatively large cyprinid endemic to the San Francisco Estuary watershed. During late winter and early spring, splittails migrate from the estuary to upstream rivers and floodplains for spawning. During 2002 and 2003, we examined the diet composition, muscle stable isotope signatures (δ13C and δ15N), and growth rates of age-0 splittails in the four primary rivers used for spawning. Overall, we found substantial variability in all three traits in spatial and temporal comparisons. Age-0 splittails consumed a variety of prey taxa, consisting almost exclusively of aquatic invertebrates, larval stages of chironomids or copepods generally being the most common. We found that the δ15N and δ13C signatures of age-0 splittails significantly varied spatially and temporally (δ15N range = 6.1–19.6%; δ13C range = –36.3 to –17.5%). Environmental conditions, namely flow and how it manipulates habitat connectivity, appeared to affect δ13C. Age-0 splittails exhibited substantial variability in growth rate both spatially and temporally. However, this variability was not associated with diet composition or stable isotope signatures, suggesting that food availability and physical habitat conditions were important factors affecting growth rates during our study.

Feyrer, F., M.L. Nobriga, and T.R. Sommer (2007). "Multi-decadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, U.S.A." Canadian Journal of Fisheries and Aquatic Sciences 64: 723-734.

We examined a 36-year record of concurrent midwater trawl and water quality sampling conducted during fall to evaluate habitat trends for three declining fish species in the San Francisco Estuary, California, USA: delta smelt (Hypomesus transpacificus), striped bass (Morone saxatilis), and threadfin shad (Dorosoma petenense). Generalized additive modeling revealed that Secchi depth and specific conductance were important predictors of occurrence for delta smelt and striped bass, while specific conductance and water temperature were important for threadfin shad. Habitat suitability derived from model predictions exhibited significant long-term declines for each species; the southeastern and western regions of the estuary exhibited the most dramatic changes. Declines in habitat suitability were associated with anthropogenic modifications to the ecosystem. For delta smelt, an imperiled annual species endemic to the estuary, the combined effects of fall stock abundance and water quality predicted recruit abundance during recent years of

chronically low food supply. Our results are consistent with existing evidence of a long-term decline in carrying capacity for delta smelt and striped bass and demonstrate the utility of long-term data sets for evaluating relationships between fish and their habitat.

Feyrer, F., J.A. Hobbs, M. Baerwald, T.R. Sommer, Q. Yin, K. Clark, B.P. May, and W.A. Bennett (2007). "Otolith microchemistry provides information complimentary to microsatellite DNA for a migratory fish." Transactions of the American Fisheries Society 136: 469-476.
We investigated the ability of otolith microchemistry to discriminate natal habitats of the splittail Pogonichthys macrolepidotus, a migratory cyprinid endemic to the San Francisco Estuary, California. Splittails are broadly distributed in the brackish and freshwater portions of the lower estuary and make long-distance upstream migrations during winter to rivers and floodplains for spawning. We found that the ratios of Sr: Ca and 87Sr: 86Sr in the otoliths (ascertained by laser ablation inductively coupled mass spectrometry) of age-0 fish collected from natal habitats significantly varied among four primary spawning rivers. Based on these two constituents, quadratic discriminant function analysis correctly classified 71% of the fish to their natal rivers. Recent work with microsatellite DNA indicates that splittails from these same rivers represent two genetically distinct populations. Thus, integrating data obtained from otolith microchemistry and microsatellite DNA can provide complementary information on the natal origin and genetic structure of splittails at any life stage. This information will be valuable for studies of the population dynamics of mixed-stock samples collected from the estuary.

Feyrer, F., J.A. Hobbs, and T.R. Sommer (2010). "Salinity inhabited by age-0 splittail (Pogonichthys macrolepidotus) as determined by direct field observation and retrospective analyses with otolith chemistry." San Francisco Estuary and Watershed Science 8(2).
Splittail (Pogonichthys macrolepidotus) is a fish species of special concern that is endemic to the San Francisco Estuary. It has been generally accepted that spawning and juvenile rearing occurs during spring in freshwater habitats upstream of the estuary. However, the recent discovery of a genetically distinct population of splittail in the relatively brackish Petaluma and Napa rivers has challenged this assumption. We used a combination of field observations and high resolution sampling of otolith 87Sr:86Sr ratios to identify the salinity inhabited by young age-0 splittail in the Sacramento, San Joaquin, Napa, and Petaluma rivers. Individual age-0 splittail, two to three months old, were observed in the Napa and Petaluma rivers in salinity as high as 8.5 ppt and 14.1 ppt, respectively, whereas salinity in the San Joaquin and Sacramento rivers was always <1.0 ppt. Otolith 87Sr:86Sr ratios corresponding to the first month of life suggested that individual splittail in all regions mostly inhabited freshwater, although several individuals from the Napa and Petaluma rivers inhabited brackish water up to about 10 ppt. In most instances, there was little intra-individual variability in 87Sr:86Sr signals, suggesting individuals remained within the natal salinity zone during the first month of life. The exceptions were two fish, one each from the Napa and Petaluma rivers, that appeared to move from freshwater natal to brackish rearing habitats. The apparent ability of age-0 splittail to rear in brackish water almost immediately after being born is one of the fundamental mechanisms supporting splittail production in the Napa and Petaluma rivers.

Feyrer, F., D. Portz, D. Odum, K.B. Newman, T. Sommer, D. Contreras, R. Baxter, S.B. Slater, and D. Sereno (2013). "SmeltCam: Underwater Video Codend for Trawled Nets with an Application to the Distribution of the Imperiled Delta Smelt." PLoS ONE 8(7).
Studying rare and sensitive species is a challenge in conservation biology. The problem is exemplified by the case of the imperiled delta smelt Hypomesus transpacificus, a small delicate fish species endemic to the San Francisco Estuary, California. Persistent record-low levels of abundance and relatively high sensitivity to handling stress pose considerable challenges to studying delta smelt in the wild. To attempt to overcome these and other challenges we have developed the SmeltCam, an underwater video camera codend for trawled nets. The SmeltCam functions as an open-ended codend that automatically collects information on the number and

species of fishes that pass freely through a trawled net without handling. We applied the SmeltCam to study the fine-scale distribution of juvenile delta smelt in the water column in the upper San Francisco Estuary. We learned that during flood tides delta smelt were relatively abundant throughout the water column and that during ebb tides delta smelt were significantly less abundant and occurred only in the lower half and sides of the water column. The results suggest that delta smelt manipulate their position in the water column to facilitate retention in favorable habitats. With the application of the SmeltCam we increased the survival of individual delta smelt by 72% compared to using a traditional codend, where all of the fish would have likely died due to handling stress. The SmeltCam improves upon similar previously developed silhouette photography or video recording devices and demonstrates how new technology can be developed to address important questions in conservation biology as well as lessen the negative effects associated with traditional sampling methods on imperiled species.

Feyrer, F. and M. P. Healey (2002). "Structure, sampling gear and environmental associations, and historical changes in the fish assemblage of the southern Sacramento-San Joaquin Delta." California Fish and Game 88: 126-138.
We sampled fishes at 11 fixed sites monthly from January 1993 through December 1994 in the Southern Sacramento-San Joaquin Delta. Using three different sampling gears (boat electrofishing, gillnets, and hoopnets), we obtained 988 samples and collected 27,791 fishes representing 33 species. Overall, the catch was heavily dominated by alien species which represented 99% of the total number of fishes we collected. We used partial canonical correspondence analysis (pCCA) to examine the effect of gear type and environmental variables on fish assemblage structure. Gear type strongly influenced the observed assemblage structure accounting for 59% of the variation explained by pCCA. Ictalurids dominated the hoopnet catches. Ictalurids, striped bass, Morone saxatilis, and splittail, Pogonichthys macrolepidotus, dominated the gillnet catches, while centrarchids dominated the electrofishing catches. Electrofishing collected approximately 50% more species than the other two gear types, suggesting that it may be the most favorable of the three to assess presence-absence, although it apparently did not sample large mobile fishes very well. After accounting for the effect of gear type, flow and water temperature had the strongest influence on assemblage structure. The south Delta fish assemblage has changed greatly since it was first described 30 years prior to our study. Two native species have apparently been extirpated and at least eight species have established reproducing populations. Our results (1) suggest that, depending upon the goals of the study, the use of a single sampling gear may provide a biased assessment of the south Delta fish assemblage and (2) corroborate the hypothesis that highly altered habitat as are vulnerable to the invasion and established of alien species.

Feyrer, F., K. Newman, et al. (2011). "Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish." Estuaries and Coasts 34(1): 120-128.
Future development and climate change pose potentially serious threats to estuarine fish populations around the world. We examined how habitat suitability for delta smelt (Hypomesus transpacificus), a state and federally protected species, might be affected by changes in outflow in the San Francisco Estuary due to future development and climate change. Forty years of sampling data collected during fall from 1967 to 2008 were examined to define abiotic habitat suitability for delta smelt as a function of salinity and water transparency, and to describe long-term trends in habitat conditions. The annual habitat index we developed, which incorporated both quantity and quality of habitat, decreased by 78% over the study period. Future habitat index values under seven different development and climate change scenarios, representing a range of drier and wetter possibilities, were predicted using a model which related estuarine outflow to the habitat index. The results suggested that each of the scenarios would generally lead to further declines in delta smelt habitat across all water year types. Recovery targets for delta smelt will be difficult to attain if the modeled habitat conditions are realized.

Feyrer, F., T. Sommer, et al. (2009). "Old School vs. new School: status of threadfin shad (Dorosoma petenense) five decades after its introduction to the Sacramento-San Joaquin Delta." San Francisco Estuary and Watershed Science 7(1).

Threadfin shad (Dorosoma petenense) is a schooling pelagic forage fish native to watersheds of the Gulf Coast of North America. Around 1962 it invaded the Sacramento-San Joaquin delta from upstream reservoirs, where it was stocked to support sport fisheries. It quickly became, and continues to be, one of the most abundant fishes collected by ongoing monitoring programs in the delta. A substantial portion of the delta provides suitable abiotic habitat and so the species is widely distributed. However, in routine sampling it is most commonly collected and most abundant in the southeastern delta, where suitable abiotic habitat (relatively deep, clear water with low flow) coincides with high prey abundance. Apparent growth rate appears to be relatively fast with summer-spawned age-0 fish attaining fork lengths of 70-90 mm by the onset of winter. During fall months (September-December) apparent growth rate of age-0 fish has exhibited no long-term trend but has been negatively related to abundance, suggesting that density-dependent factors may be important to the population. Although abundance has fluctuated since its introduction almost five decades ago, it has recently dropped to persistent near-record lows since 2002, which has been coincident with similar declines for other pelagic species in the delta. The recent decline is apparent in two long-term monitoring programs, fish salvaged from the diversions of the State and Federal Water Projects, and commercial fishing harvest. It appears that the decline is, at least in part, a function of fewer and smaller schools of threadfin shad encountered relative to the past. There was little evidence from the data examined for consistent stock-recruit or stage-recruit effects on the population. It is likely that a combination of abiotic and biotic factors regionally-focused where threadfin shad are most abundant, which may sometimes be episodic in nature, have a large effect on abundance. Focused studies and sampling of threadfin shad are lacking but are necessary in order to better understand population dynamics in the delta.

Finlayson, B. J. and G. A. Faggella (1986). "Comparison of laboratory and field observations of fish exposed to the herbicides molinate and thiobencarb." Transactions of the American Fisheries Society 115: 882-890.

Acute toxicity tests with the rice herbicides molinate (Ordram)) and thiobencarb (Bolero)) and with thiobencarb-molinate mixtures on juvenile steelhead Salmo gairdneri , chinook salmon Oncorhynchus tshawytscha , channel catfish Ictalurus punctatus , and striped bass Morone saxatilis produced median lethal concentrations (96-h LC50 values) indicating that thiobencarb (0.76-1.8 mg/L) was 11 to 19 times more toxic than molinate (8.1-34 mg/L); thiobencarb-molinate mixtures at 1:1 LC50-value ratios had additive toxic effects on steelhead, chinook salmon, and channel catfish. Chronic toxicity tests with molinate produced 28-d no-observable-effect-level and lowest-observable-effect-level values for survival and hematology of 0.09 and 0.13 mg/L, respectively, for common carp Cyprinus carpio , and 1.7 and 2.6 mg/L, respectively, for channel catfish. Observations made on mortality and hematology of common carp, white catfish Ictalurus catus and channel catfish in agricultural drains containing the herbicides were compared to effects determined in laboratory toxicity tests.

Finlayson, B. J. and K. M. Verrue (1980). "Estimated safe zinc and copper levels for chinook salmon, Oncorhynchus tshawytscha , in the upper Sacramento River, California." Calif. Fish Game 66(2): 68-82.

Long-term (83-d) and short-term (96-h) toxicity tests with combined copper and zinc solutions were conducted on O. tshawytscha eggs, alevins, and swim-up fry to determine tolerance levels to copper and zinc in the acid-mine waste from Spring Creek. The ratio of copper-to-zinc in the waste can vary betweeen 1:2 and 1:12. Eggs were as tolerant as alevins and fry to combined concentrations of copper and zinc. The 83-d LCSUB-50 values for the period of eggs-to-fry to 1:3, 1:6, and 1:11 copper-to-zinc ratio stock solutions were 44 g/l Cu and 160 g/l Zn, 27 g/l Cu and 206 g/l Zn, and 17 g/l Cu and 253 g /l Zn, respectively, demonstrating that the toxicities of copper and zinc were 'additive'. The 96-h LCSUB-50 values for fry not previously exposed to the stock solutions were 37 g/l Cu and 132 g/l Zn, 29 g/l Cu and 213 g/l Zn, and 20 g/l Cu and 279 g/l Zn, for the same copper-to-zinc ratio stock solutions, respectively, demonstrating that an acclimation to these metals had

occurred in the 83-d tests during embryonic and alevin development at the higher (1:3) copper-to-zinc ratio but not at the lower (1:6 and 1:11) copper-to-zinc ratios. Estimated 'safe' levels of copper and zinc for chinook salmon would be <11 and <93 g/l, respectively.

Fisch, K., . T. Rettinghouse, L. Ellison, G Tigan, J. Lindberg, and B. May (2009). Delta Smelt Refugial Population Development & Genetic Management - 2009 Season Summary. IEP Newsletter. 22: 7.

Fisch, K., B. Majardja, T Retinghouse, L. Ellison, G. Tigan, J. Lindberg, B May (2010). Captive Breeding Plan for the Endangered Delta Smelt: Genetic Management and Fish Rearing Modifications for 2010. IEP Newsletter. 23: 8.

Fisch, K., R.S. Burton, and B. May (2010). Conservation genetics of delta smelt (Hypomesus transpacificus): Population genetics, hybridization & captive population genetic management. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Delta smelt (Hypomesus transpacificus) are endemic to the San Francisco Bay-Delta (SFBD). Once abundant, numbers of delta smelt declined dramatically in the early 1980's, and the species has been listed as threatened since 1993. To assess wild delta smelt population genetics and to analyze the genetic signature of the decline, we conducted a population genetic study using sixteen microsatellite DNA markers to assess the geographic and temporal population structure of delta smelt, assessed hybridization between delta smelt and wakasagi and longfin smelt, and genetically monitored the captive delta smelt refugial population. We genetically analyzed samples collected by the California Department of Fish & Game from the 2003, 2005, 2007 & 2009 Spring Kodiak Trawl Survey, consisting of delta smelt collected from fourteen unique geographic locations and from three generations in captivity. For the hybridization study, we genetically analyzed fish using the 16 microsatellite markers and sequenced all three species and potential hybrid fish for nuclear and mitochondrial DNA loci. To test the null hypotheses, we analyzed the number of alleles per locus, observed heterozygosity, expected heterozygosity, allelic richness, Hardy-Weinberg equilibrium, linkage disequilibrium, F-statistics, and utilized the program STRUCTURE. The null hypotheses are as follows: 1. Populations of delta smelt in the SFBD do not vary geographically or temporally in genetic diversity and/or population structure, 2. Delta smelt hybridization with longfin smelt and/or wakasagi smelt is not prevalent throughout the SFBD, and 3. Genetic management of the captive delta smelt population maintains genetic diversity effectively. The relevance of this study to Bay-Delta management includes the potential need for dynamic management of delta smelt populations, including hybridization control, as well as increased support for the effectiveness of the genetic management plan of the captive delta smelt population, which aims to preserve the species in the event of extinction in the wild.

Fisch, K., J. Henderson, et al. (2011). "Population genetics and conservation implications for the endangered delta smelt in the San Francisco Bay-Delta." Conservation Genetics 12(6): 1421-1434.

Fisch, K. M., R.S. Burton, and B.P. May (2010). Genetic structure of delta smelt in the San Francisco Estuary. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Fisch, K. M., J. L. Petersen, et al. (2009). "Characterization of 24 microsatellite loci in delta smelt, Hypomesus transpacificus, and their cross-species amplification in two other smelt species of the Osmeridae family." Molecular Ecology Resources 9(1): 405 - 408.

We characterized 24 polymorphic tetranucleotide microsatellite loci for delta smelt (Hypomesus transpacificus) endemic to the San Francisco Bay Estuary, CA, USA. Screening of samples (n = 30) yielded two to 26 alleles per locus with observed levels of heterozygosity ranging from 0.17 to 1.0. Only one locus deviated from Hardy–Weinberg equilibrium, suggesting these individuals originate from a single panmictic population. Linkage disequilibrium was found in two pairs of loci after excluding the locus out of Hardy–Weinberg equilibrium. Twenty-two primer pairs cross-amplified in wakasagi smelt (Hypomesus nipponensis), and 15 primer pairs cross-amplified in longfin smelt (Spirinchus thaleichthys).

Fish, M., D. Contreras, V. Afentoulis, J. Messineo, and K. Hieb (2009). 2008 Fishes Annual Status and Trends Report for the San Francisco Estuary. iEP Newsletter. 22: 29.

Fish, M. A. (2010). A White Sturgeon Year-Class Index for the San Francisco Estuary and Its Relation to Delta Outflow. IEP Newsletter. 23: 5.

Fisher, A. C., W. M. Hanemann, et al. (1991). "Integrating fishery and water resource management: A biological model of a California salmon fishery." Journal of Environmental Economics and Management 20(3): 234-261.

In this paper we develop a model to simulate the impacts of changes in freshwater flows into and out of the San Francisco Bay/Delta on the California Central Valley salmon fishery. The model also describes interactions among these water flow controls, hatchery operations, and harvest regulation. Traditionally, the management of California's freshwater resources and anadromous fisheries has been undertaken separately, in the literature and in practice. We demonstrate the potential gains from a coordinated management approach.

Fisher, F. W. (1994). "Past and present status of Central Valley chinook salmon." Conservation Biology: the journal of the Society for Conservation Biology 8(3): 870-873.

California's Central Valley chinook salmon populations are a fragment of their former abundance. Water development for hydroelectric production, irrigation, domestic water supplies, and flood control has restricted or eliminated much of the natural habitat formerly occupied by Central Valley salmon. Much of the species historical habitat has been replaced by hatcheries. Where certain runs are difficult to domesticate for hatchery culture, only isolated population remnants remain.

Fisher, R. N., and H.B. Shaffer (1996). "The decline of amphibians in California's Great Central Valley." Conservation Biology 10(5): 1387-1397.

Declines in amphibian populations are rarely reported on the community or ecosystem level. We combined broad-scale field sampling with historical analyses of museum records to quantify amphibian declines in California’s Great Central Valley. Overall, amphibians showed an unambiguous pattern of decline, although the intensity of decline varied both geographically and taxonomically. The greatest geographical decline was detected in the counties of the Sacramento and San Joaquin Valleys. Two species, Rana aurora and Bufo boreas were identified as the most affected by decline, whereas Pseudacris regilla was the least affected. The Coast Range counties had little or no detectable decline. We provide new evidence implicating introduced predators as a primary threat. Introduced predators occur at lower elevations than native species, and our data indicate that for some native species there has been significant restriction to higher elevation sites from a formerly broader distribution. Our historical approach provides a strategy for identifying declining amphibian communities that complements more detailed, long-term monitoring programs and provides an assessment of the pattern of change that is a necessary prerequisite for the development of field experiments that test hypothesized mechanisms of change.

Fleck, J., D. Krabbenhoft, M. Stephenson, and B.A. Bergamaschi (2010). Methylmercury and organic matter in Delta wetlands: observed trends, linkages and management impacts. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Sea-level rise, levee instability, ecosystem restoration, subsidence mitigation, water diversions and impacts of climate change will alter the landscape of the Sacramento-San Joaquin Delta, with most scenarios predicting a greater extent of inundation and an expansion of wetland area. Wetlands provide many important functions for ecosystems, but they are also known primary sites for the formation of methylmercury (MeHg), and the expansion of wetlands in the future Delta could pose a greater potential threat to human and ecosystem health through higher exposure to this potent neurotoxin. The formation of MeHg has been demonstrated to be linked to the abundance of organic matter (OM) in a multitude of natural systems with the relationship varying largely upon the extent of wetland coverage within the watershed. Because of this coupling, understanding the concurrent cycling of OM and MeHg can provide insights into the processes controlling MeHg in the water column. Over the past five years, the USGS and partners have collected concurrent measurements of OM, Hg and MeHg in the waters of a wide range of wetlands within the Delta ecosystem including tidal wetlands, impounded flow-through wetlands, seasonal and permanent ponds, shore-bird ponds and various rice fields. Although OM and MeHg were tightly coupled across the range of natural wetlands examined by this study, no relationship was observed within or across the managed wetlands. Causes for the lack of correlation were attributed to several possible mechanisms: 1) the decoupling of OM and MeHg production processes, 2) increased recycling and degradation processes, 3) impacts on biotic uptake, partitioning and cycling via algal activity and 4) differences in controls on diffusive and advective exchange between water and sediment. The information gathered through these studies suggests simple management actions may be utilized to minimize Hg and MeHg exports from wetlands in today’s and tomorrow’s Delta.

Fleenor, W., and L. Doyle (2010). Modeling the historical Delta. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Increasing attention has been focused on the Sacramento-San Joaquin Delta as the ecosystem continues to decline and the water supply reliability suffers. Most agree about the complexity of the Delta (Moyle et al. 2010), but discussions on the solutions continue to be varied. Estimating human demands for water, both in quantity and quality, is fairly straightforward with well-established methods. Estimating flows for improving habitat conditions, particularly to support fishes with different and often conflicting life history strategies, is much more complex and is hampered by numerous uncertainties. Methods have been proposed that include scientific evidence to support suggested environmental flows (Fleenor et al. 2010). Anthropogenic modifications to the Delta began in 1849 and the physical changes to the Delta were mostly completed over a 60-year period ending in 1910. Upstream consumptive use of Delta water began during the physical development of the Delta and was mostly developed by 1920 (Thompson 1958, Hundley 2001). Additional hydraulic infrastructure was built during the 1940-1965 period to control flows and export water south. Manipulation of Delta flows continues today to control water quality and export levels. More recently, environmental flow requirements have increased stress between environmental and water supply interests. However, current efforts all utilize recently collected data to determine what is best for desired biota in the current Delta configuration. To provide a more historical perspective of the water use changes on Delta habitat, a modeling effort has been undertaken to reverse engineer the Delta hydraulic regime. The approach was to examine the changes in the reverse order in which they occurred, effectively turning the clock backwards. Early results will be presented showing the effects, against a base case, of the Sacramento Deep Water Ship Channel, the creation of the Stockton Deep Water Ship Channel, and the early 20th century modifications of channel changes within the Delta. It is hoped that the approach taken will bring additional information of the habitat changes to the Delta.

Flegal, A. R. (1977). Mercury in the seston of the San Francisco Bay estuary.
Measurements taken from samples collected from the San Francisco Bay estuary demonstrated that the relatively high concentration of mercury (0 . 25 mu g/g) in the surface sediments is paralleled in the seston. Plankton net tows of 20 mu m, 76 mu m and 366 mu m were used for sample collection and aliquots of each sample were analysed for mercury by shift atomic absorption spectrophotometry. The mercury concentrations (mu g/g dry wt) and percentage ash weight of the samples are listed. From the results, only a direct assessment of the amount of mercury in the 20 mu m samples could be made. This macro-seston contains relatively high concentrations of mercury. The levels vary temporarily and spatially with the size fraction of the seston and its organic content, and appear to be higher in the phytoplankton and/or organic detritus than in the zooplankton.

Flegal, A. R., C. L. Brown, et al. (2007). "Spatial and temporal variations in silver contamination and toxicity in San Francisco Bay." Environmental Research 105(1): 34-52.
Although San Francisco Bay has a ''Golden Gate'', it may be argued that it is the ''Silver Estuary''. For at one time the Bay was reported to have the highest levels of silver in its sediments and biota, along with the only accurately measured values of silver in solution, of any estuarine system. Since then others have argued that silver contamination is higher elsewhere (e.g., New York Bight, Florida Bay, Galveston Bay) in a peculiar form of pollution machismo, while silver contamination has measurably declined in sediments, biota, and surface waters of the Bay over the past two to three decades. Documentation of those systemic temporal declines has been possible because of long-term, ongoing monitoring programs, using rigorous trace metal clean sampling and analytical techniques, of the United States Geological Survey and San Francisco Bay Regional Monitoring Program that are summarized in this report. However, recent toxicity studies with macro-invertebrates in the Bay have indicated that silver may still be adversely affecting the health of the estuarine system, and other studies have indicated that silver concentrations in the Bay may be increasing due to new industrial inputs and/or the diagenetic remobilization of silver from historically contaminated sediments being re-exposed to overlying surface waters and benthos. Consequently, the Bay may not be ready to relinquish its title as the ''Silver Estuary''.

Flegal, A. R., C. H. Conaway, et al. (2005). "A review of factors influencing measurements of decadal variations in metal contamination in San Francisco Bay, California." Ecotoxicology 14(6): 645-660.
This review summarizes some of the principal results of systematic measurements of trace metal concentrations throughout San Francisco Bay that began in 1989, and that have yielded insights on the factors controlling temporal and spatial variations of those concentrations on seasonal to decadal time scales. Pronounced seasonal variation in some metal concentrations is associated with gradients in the system's hydrology and the diagenetic remobilization of metals from benthic sediments. Additional temporal variation is associated with interannual differences in hydrologic flushing (e.g., ENSO cycles) and episodic storm events. While intra- and inter-annual variabilities complicate assessments of long-term variations in metal concentrations, recent analyses using stable lead isotopic composition distributions and time-series models have deconvoluted decadal changes in lead and silver concentrations in the estuary. Decadal variations in concentrations of other contaminant metals (e.g., mercury) are now being characterized, as well as projections of future concentrations of other metals of concern (e.g., copper). These historic assessments and projections of trace metal variations attest to the importance of long-term, systematic monitoring programs to quantify past and future impacts on water quality in San Francisco Bay and other complex estuarine systems.

Flegal, A. R., J. A. Davis, et al. (2007). "Sources, transport, fate, and toxicity of pollutants in the San Francisco Bay estuary." Environmental Research 105(1): 0-4.

Flegal, A. R., I. Rivera-Duarte, et al. (1996). Metal contamination in San Francisco Bay waters: Historic perturbations, contemporary concentrations and future considerations. San Francisco Bay: The Ecosystem. J. T. Hollibaugh. San Francisco, AAAS: 173-188.

Flegal, A. R. and S. A. Sanudo-Wilhelmy (1993). "Comparable levels of trace metal contamination in two semi-enclosed embayments: San Diego Bay and South San Francisco Bay." Environmental Science and Technology 27(9): 1934-1936.
The following preliminary analyses of total dissolved (<0.4 mu m) trace element (Ag, Cd, Co, Cu, Ni, and Pb) concentrations in San Diego Bay are comparable to the levels of trace element contamination in the southern reach of the San Francisco Bay estuary. The latter area, which is referred to as the South Bay, is hydraulically similar to San Diego Bay. Both are semienclosed embayments with limited natural freshwater inputs. Those inputs have been further reduced by a protracted drought throughout California that has extended over the past 6 years and

may have exacerbated problems of contamination in the two bays. Still, the similarities in trace element concentrations in San Diego Bay and South Bay are surprising, because anthropogenic inputs of contaminants to the two systems are substantially different. Elevated concentrations of copper and nickel in saline waters of the South Bay have been positively correlated to wastewater discharges from municipal (2.4 x 10 super(11) L/year) and industrial (6.9 x 10 super(9) L/year) discharges, which account for approximately 40% of the "freshwater" (i.e., low salinity) inputs to the South Bay. [The remaining 60% is derived from urban surface runoff (3.9 x 10 super(11) L/year).] However, elevated trace element concentrations in San Diego Bay cannot be directly linked to point-source inputs, since all wastewater discharges to that bay were terminated in 1964. Therefore, other processes (e.g., sedimentary fluxes, surface runoff) must be involved in the regulation of trace element concentrations in San Diego Bay.

Flegal, A. R., G. J. Smith, et al. (1991). "Dissolved trace element cycles in the San Francisco Bay Estuary." Marine Chemistry 36(1-4): 329-363.
Dissolved trace element (copper, nickel, cadmium, zinc, cobalt, and iron) concentrations were measured in surface water samples collected from 27 stations in the San Francisco Bay and Sacramento-San Joaquin Delta during Apr., Aug. and Dec. 1989. The trace element distributions were relatively similar for all three sampling periods, and evidenced two distinct biogeochemical regimes within the estuarine system. The two regimens were comprised of relatively typical trace element gradients in the northern reach and anthropogenically perturbed gradients in the southern reach of the estuary. These dichotomous trace element distributions were consistent with previous reports on the distributions of nutrients and some other constituents within the estuary.

Fleishman, E., and L.R. Brown (2010). Collaborative workgroup efforts to model species, stressors, and processes in the upper San Francisco Estuary. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Since May 2007, collaborative workgroups facilitated by the University of California, Santa Barbara in partnership with the Interagency Ecological Program have sought to better understand patterns and drivers of the decline of pelagic fishes in the upper San Francisco Estuary and the status and trend of the ecosystem. Workgroups have focused on ecosystem modeling, contaminants effects, and interactions between the near-coastal ocean and San Francisco Estuary. The ecosystem modeling group examined trends in abundance of delta smelt, longfin smelt, threadfin shad, and striped bass. Participants evaluated evidence for abrupt changes in abundances and whether selected covariates were correlated with those changes. Additionally, participants are modeling the static and dynamic food web of the ecosystem. The contaminants group investigated whether assessment of the cumulative effects of pesticides on species or ecological functions might be transferred more effectively to decision makers. The group reviewed the spatial overlap between life stages of pelagic fishes and the mechanisms by which contaminants may contribute to declines. Furthermore, the group is examining land-use change in the region from 1990 to 2006 and chemicals associated with urban runoff in key locations occupied by pelagic fishes. The near-coastal group is exploring how a pronounced shift in climatic forcing of the Pacific Ocean, measured as the North Pacific Gyre Oscillation, may affect populations of species that migrate between oceans and estuaries. We are documenting data and metadata to ensure that scientific sources and methods are transparent and, where applicable, repeatable. We also are pursuing mechanisms other than scientific journals to communicate results to a broad audience of end users, including stakeholders and policy makers.

Fleskes, J. P., W. M. Perry, et al. (2005). "Change in area of winter-flooded and dry rice in the Northern Central Valley of California determined by satellite imagery." California Fish and Game 91(3): 207-215.
To understand possible factors impacting distribution of wintering waterfowl, we analyzed satellite imagery to estimate area of winter-flooded (flooded and saturated soil) and winter-dry harvested rice in Butte, Colusa, American, Sutter, Yolo, and Delta basins in the northern Central Valley of California. We compared our results for the 1999-00 winter with estimates that Spell et al. (1995)

reported using identical methods for 1988-89 and 1993-94. Area of winter-flooded rice in the northern Central Valley in 1999-00 (78,841 ha) was 37% greater than in 1993-94 (57,702 ha) and 46% greater than in 1988-89 (53,816 ha). Winter-flooded rice increased an average of 3,253 ha per year between 1993-94 and 1999-00 compared to 777 ha per year between 1988-89 and 1993-94. The increase in flooded rice area was due to both an increase in total rice area (201,512 ha in 199900 vs. 171,918 ha in 1993-94 and 163,586 ha in 1988-89) and an increase in percentage of rice area that was flooded (39% in 1999-00 vs. 34% in 1993-94 and 33% in 1988-89). Change in winter-flooded rice area varied among basins. These results will help understand changes in distribution of wintering waterfowl among Central Valley basins during 1988-2000. The challenge for wildlife managers is to develop strategies that incorporate impacts of the increase in rice area in the northern Central Valley while recognizing that various factors could reduce rice area in the future.

Flint, L., A. Flint, S. Weiss, and L. Micheli (2010). Estimating future habitat resiliency and water availability in the North Bay region using fine-scale modeling. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Preparing for climate change in terms of water supply, water quality, flooding, and habitat requires estimating potential changes to climate, hydrology, and ecosystems based on the best science available at the watershed scale. Available climate projections require spatial downscaling for hydrologic model application and when applied at very fine scales, provide the ability to fully characterize the landscape and potential water supply under changing environmental conditions. This project focused on land managed by the North Bay Watershed Association, incorporating the Napa River and Sonoma Creek drainages, and watersheds in Marin County draining to the bay and coast. Climate change projections (NCAR’s Parallel Climate Model and Geophysical Fluid Dynamics Laboratory model for two emission scenarios, A2 and B1) for the next century were downscaled to 270-m and used in a regional water balance model to simulate future conditions of runoff, recharge, evapotranspiration, soil moisture, and climatic water deficit to help characterize the full suite of environmental changes that may occur in these watersheds. Results from this fine-scale modeling indicate for all scenarios that the ecosystems will become more stressed, increasing in average climatic water deficit. However, the change is not the same throughout the whole region and connectivity required for habitat resiliency is likely to be maintained in many locations over the next century. Small areas may be available as refugia to maintain vegetation populations and associated fauna. The projected impact of climate change on water availability for fisheries and human use is less certain but water availability likely to be reduced in some basins as it becomes more extreme or variable in other basins.

Floerke, W. a. W. T. (2011). "Benthic Bioguide." from http://www.water.ca.gov/bdma/BioGuide/BenthicBioGuide.cfm.
The Benthic BioGuide is funded by the California Interagency Ecological Program (IEP) for the purpose of providing a comprehensive source for biological, ecological and identification information for common and important benthic invertebrates of the upper San Francisco Estuary (SFE). The Benthic BioGuide is a living document that is constantly being updated as new information becomes available. The initial idea was hatched by Cindy Messer and a poster paper (pdf, 240 bk)was produced by Rachel Barnett and Sabrina Bell for the “2007 State of the San Francisco Estuary Conference”. During summer and fall of 2011, Wyatt Floerke and Bill Templin, worked on this version of the bioguide for the first 10 (of 40) most common species.

Flores, I., C. Teh, M. Kawaguchi, S. Lesmeister , C. Foe, and S.J. Teh (2010). Acute and chronic toxicity of ammonia on Pseudodiaptomus Forbesi. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Flory, S., B. Sunderland, A. Cohen, and S. Mayr (2010). A house built on rock: the advanced bathymetric data revolution. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Foe, C. and A. Knight (1985). "The effect of phytoplankton and suspended sediment on the growth of Corbicula fluminea (Bivalvia)." Hydrobiologia 127(2): 105-115.
Juvenile C. fluminea Mueller (1774) were cultured at 15.3 degree C in the laboratory on 8 combinations of suspended sediment and phytoplankton. Sediment concentrations were 2.6, 25, 50, and 150 mg/l super(-1). Chlorophyll a levels were 15.6 and 62.5 mu g/l super(-1). Clam tissue growth was found to be independent of silt concentration but increased at the higher chlorophyll level ($p < 0.05$). The growth experiment was repeated at 24 degree C with chlorophyll a concentrations of 18.9 and 112.6 mu g/l super(-1). Growth was again greater at the higher phytoplankton level ($p < 0.05$). These results demonstrate that Asiatic clam populations are food-limited most of the growing season in the northern and western portions of California's eutrophic Sacramento-San Joaquin Delta where chlorophyll a levels average less than the lower of these values. Comparisons of clam growth in the laboratory and estuary support the food limitation hypothesis as at the higher food concentration laboratory tissue growth was 2.3 and 3.8 times greater during the high and low temperature evaluations than in the estuary.

Fong, P. P. (1991). "The effects of salinity, temperature, and photoperiod on epitokal metamorphosis in Neanthes succinea (Frey et Leukart) from San Francisco Bay." Journal of Experimental Marine Biology and Ecology 149(2): 177-190.
The combined effects of salinity, temperature, and photoperiod on the frequency of epitokal metamorphosis in the semelparous polychaete Neanthes succinea were examined in laboratory experiments. Worms metamorphosed significantly more often and sooner in salinities of 20 ppt than of 5 ppt Worms maintained at 5 ppt for 10-12 months, and then gradually exposed to higher salinities up to 20 ppt also metamorphosed more readily than controls kept at 5 ppt. Neither temperature nor photoperiod alone had a significant effect on the frequency of epitokal metamorphosis, but salinity and temperature had an effect on timing and synchronization.

Foott, J. S., and J. Bigelow (2010). Disease Occurance in Adult Delta Smelt Captured in Sacramento River Kodiak Trawl, 2010. IEP Newsletter. 23: 7.

Foott, S. and J. Biglow (2010). "Pathogen survey, gill Na-K-ATPase activity, and leukocyte profile of adult delta smelt." California Fish and Game 96 (40): 223-231.
105 adult delta smelt collected from the lower Sacramento River between January and May 2010 were analyzed for the presence of infections pathogens (viruses, bacteria, or parasites), tissue abnormalities (gill, liver, intestinal tract), peripheral blood cell profile, and gill Na-K-ATPase activity. The lack of clinical signs or morbidity, few tissue changes or significant parasitic infections observed in histological specimens, or microbiological isolations, indicate that these fish were apparently healthy. A high incidence of asymptomatic Mycobacterium sp. infection (54%) was detected by PCR, but this bacterial group was not isolated in culture and the carrrier-state infections were not determined to pose a significant health problem for the sample population.

Ford, T., and L.R. Brown (2001). Distribution and abundance of chinook salmon and resident fishes of the lower Tuolumne River, California. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 253-304.
The Tuolumne River chinook salmon (Oncorhynchus tshawytscha) population represents one of the southernmost populations of the species and is of considerable management interest. This paper compiles and analyzes data available through 1997 for chinook salmon and other fish species occurring in the lower Tuolumne River. Estimates of adult fall-run chinook salmon varied from about 100 to 130,000 from 1940 to 1997 (mean: 18,300; median: 7,100). Age composition varied widely from 1981 to 1997; however, three-year-old fish usually dominated the population. The percentage of females in the population varied from 25% to 67% during 1971–1997. The percentage of tagged adult salmon increased from less than 2% before 1987 to an average of 20% during 1992–1997. Density of juvenile chinook salmon generally declined each year after a winter peak in fry abundance. Average, minimum, and maximum fork length of juvenile chinook salmon typically increased after February; although, declines occurred in some years because of large captures of fry in late

spring. Few juvenile chinook salmon resided in the river over the summer during 1988-1993. A total of 33 taxa of fish (12 native and 21 introduced), including chinook salmon, was captured during various sampling programs. Native species were most frequent in upstream areas above river kilometer (rkm) 80. Introduced species dominated areas downstream of rkm 50. The resident fish community appeared to vary in response to annual differences in flow conditions with
native species becoming more abundant in the year following a high flow year. There was no discernible seasonal change in fish communities when early summer (early June) and late summer (mid September) samples from the same sites were compared. Monitoring of the Tuolumne River chinook salmon population has provided valuable data on both chinook salmon and populations of other fish species.

Foss, S. (2004). Fish salvage at the State Water Project and Central Valley Project fish facilities. IEP Newsletter. 2: 6.

Foss, S. F. and L. W. Miller (2004). Growth and Growth Rate Variability of Larval Striped Bass in the San Francisco Estuary, California. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 203-217.
We investigated factors affecting growth of larval striped bass Morone saxatilis in the San Francisco Estuary from 1984 to 1993. We estimated ages and growth rates of larval striped bass from daily otolith increments. Mean annual growth rates of 6-14 mm standard length striped bass varied from 0.13 to 0.27mm/d, the lowest rate occurring in 1989 and the highest in 1992. The 1989 growth rate was significantly lower than all other years, and growth rates for 1992 and 1993 were significantly higher than all other years, but did not differ from one another. Differences in annual growth rates apparently were due mainly to differences in mean annual prey densities because growth rate increased as prey density increased. Compared to both laboratory measured growth rates and growth rates of field-caught Chesapeake Bay larvae, growth rates from the San Francisco Estuary appeared to be high for the food available, indicating that larvae can grow at relatively high rates even at low prey densities. Correlation analyses did not support density-dependent control of growth rates. Growth rate was not significantly related to mean annual conductivity, water temperature, mortality rates, or the juvenile abundance index, but was significantly and positively correlated with densities of 1-mm length-groups of 9-14-mm striped bass.

Fotherby, L., B. Greimann, J. Huang, and C. Young (2010). SRH-1DV vegetation modeling of the Sacramento River. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Alterations in management actions, including flow, can have minimal or broad impact on vegetation and habitat, yet vegetation response to changes in management actions are complex and difficult to predict with conceptual evaluations. Known but complex links between physical and environmental river factors are simulated with Reclamation’s SRH-1DV model as part of the North of the Delta Offstream Storage (NODOS) Investigation. This one-dimension model integrates topography and flow, with computations of hydraulics, sediment transport, groundwater surface, and the establishment, growth and mortality of riparian vegetation. Six riparian vegetation types: Fremont cottonwood (Populus Fremontii), mixed forest, Gooding’s black willow (Salix gooddingii), narrow leaf willow (Salix exigua), invasive riparian plants, and herbacious plants are included in a simulation of the Sacramento River floodplain from Red Bluff to Colusa. Results from laboratory studies by the Stockholm Environment Institute on Fremont cottonwood growth and desiccation mortality are used to enhance the model through code and input values. After incorporating improvements, changes in GIS vegetation mapping between 1999 and 2007, are compared to modeled vegetation changes over the same period. Cottonwood growth was calibrated in a previous model to field measurements at three Sacramento River bar sites, and the calibrated values are validated in this study. Four additional vegetation types are calibrated (excluding herbaceous) to the difference between the two sets of GIS vegetation mapping. Comparisons are made between general categories of forests, riparian vegetation, and invasive riparian vegetation. Modeling predictions indicate a 6% increase in forests (a combination of cottonwood and mixed forests) and the mapping value is a 0% increase for the same category (an average of cottonwood and

all individual woody vegetation classifications). Modeling predictions are a 36% increase in riparian vegetation (Gooding’s black willow and narrow leaf willow) and the mapping value is a 40% increase (Riparian scrub and riparian vegetation). Modeling predictions are a 60% increase in riparian invasive plants, mapping values indicate a 71% increase. Study results also provide quantitative information on location of new plant establishment and on location of plant mortality due to inundation, dessication, erosion and shading. Results indicate the SRH-1DV Sacramento River model is an effective tool for evaluating environmental impacts from proposed management actions, prior to implementation of actions in the field.

Fox, J. P., T. R. Mongan, et al. (1990). "Trends in freshwater inflow to San Francisco Bay from the Sacramento-San Joaqun Delta." Water Resources Bulletin 26: 1-16.

Fram, J. P., M. A. Martin, et al. (2007). "Dispersive fluxes between the coastal ocean and a semienclosed estuarine basin." Journal of Physical Oceanography 37(6): 1645-1660.
Scalar exchange between San Francisco Bay and the coastal ocean is examined using shipboard observations made across the Golden Gate Channel. The study consists of experiments during each of the following three "seasons": winter/spring runoff (March 2002), summer upwelling (July 2003), and autumn relaxation (October 2002). Within each experiment, transects across the channel were repeated approximately every 12 min for 25 h during both spring and neap tides. Velocity was measured from a boat-mounted ADCP. Scalar concentrations were measured at the surface and from a tow-yoed SeaSciences Acrobat. Net salinity exchange rates for each season are quantified with harmonic analysis. Accuracy of the net fluxes is confirmed by comparison with independently measured values. Harmonic results are then decomposed into flux mechanisms using temporal and spatial correlations. In this study, the temporal correlation of cross-sectionally averaged salinity and velocity (tidal pumping flux) is the largest part of the dispersive flux of salinity into the bay. From the tidal pumping flux portion of the dispersive flux, it is shown that there is less exchange than was found in earlier studies. Furthermore, tidal pumping flux scales strongly with freshwater flow resulting from the density-driven movement of a tidally trapped eddy and stratification-induced increases in ebb-flood frictional phasing. Complex bathymetry makes salinity exchange scale differently with flow than would be expected from simple tidal asymmetry and gravitational circulation models.

Friedman, C. S., H. M. Brown, et al. (2005). "Pilot study of the Olympia oyster Ostrea conchaphila in the San Francisco Bay estuary: description and distribution of diseases." Diseases of Aquatic Organisms 65(1): 1-8.
Olympia oysters Ostrea conchaphila have declined markedly during the last century and are a focus of restoration in many embayments, including the San Francisco Bay (SFB) estuary. Oysters were collected from 17 sites in this estuary and nearby Tomales Bay in an effort to characterize diseases that may impact recovery of this species and captive rearing programs. Three diseases/disease agents including a Mikrocytos-like protist (microcell), a haplosporidian and hemic neoplasia were observed from several sites along the western margins of the SFB estuary suggesting a geographic localization of disease presence. Based on fluoresecent in situ hybridization (FISH) assays, the microcell is distinct from M mackini and Bonamia spp. These data highlight the need for further elucidation of the haplosporidian and for careful health management of a declining species destined for captive rearing and supplementation.

Fringer, O. B., Y.J. Chou, S.L. Chua, J.R. Koseff, and S.G. Monismith (2010). Three-dimensional modeling of sediment dynamics in San Francisco Bay using the SUNTANS model. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
We employ the unstructured-grid SUNTANS model to simulate hydrodynamics and sediment transport in San Francisco Bay. The domain extends offshore of the Golden Gate by 25 km where sea-surface tidal constituents at Point Reyes are imposed, and the Delta is modeled as a "false Delta" with two rectangular boxes at the confluence of the Sacramento and San Joaquin Rivers. With an average horizontal resolution of 200 m and a minimum vertical resolution of 25 cm, the model is calibrated to produce

accurate predictions of sea-surface height, salinity, and depth-averaged currents throughout the Bay. Cohesive suspended sediment transport is modeled with the transport equation with a settling term that accounts for flocculation using results from observations, and this suspended sediment interacts with a multilayer bed model with five layers ranging in thickness from 25 mm to 1 m. A phase-averaged wave model is employed to incorporate the effects of wind-wave induced sediment resuspension. We demonstrate the behavior of the combined hydrodynamics-sediment-wave model and focus on comparisons to observations in South Bay, and we demonstrate the sensitivity of the results to the relative effects of tides and wind-waves.

Fry, B. (1999). "Using stable isotopes to monitor watershed influences on aquatic trophodynamics." Canadian Journal of Fisheries and Aquatic Sciences 56(11): 2167-2171.
Stable C and N isotope measurements of the clam Potamocorbula amurensis were used to help identify watershed-level differences in food webs of San Francisco Bay. Potamocorbula amurensis has become widely distributed in San Francisco Bay since introduction from Asia in1986. Clam samples were collected from both the river-influenced northern arm of San Francisco Bay and the lagoonal southern arm of the Bay during 1990-1991. Carbon isotopic compositions of clams responded primarily to riverine inputs and provided an index of hydrologic mixing across the estuarine system. Nitrogen isotopic compositions of clams were more responsive to watershed nutrient loading, with higher δ15N values found in South Bay, which receives stronger inputs of anthropogenic N. Routine monitoring of animal consumer isotopic compositions could be an effective way to detect long-term watershed-level changes in C and N dynamics important for secondary production in aquatic systems.

Fulfrost, B., and D. Thomson (2010). Using remote sensing to map the evolution of marsh vegetation in the south Bay of San Francisco. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The South Bay Salt Pond (SBSP) Restoration Project is the largest Federal restoration effort outside of the Everglades. The accretion of sediment and subsequent colonization of vegetation by endemic marsh vegetation is a crucial component of the restoration effort. Classic field mapping efforts to cover the vast geographic area included in the restoration project would be extremely time consuming and costly, especially over time. We have implemented a semi-automated approach to mapping vegetation and sediment on a yearly basis by using supervised classification (maximum likelihood) of 1 meter Ikonos multispectral imagery accompanied by extensive ground truthing using sub meter GPS. Our ground truthing includes efforts at characterizing vegetation associations found in salt, brackish and fresh water marshes within the study area are supplemented by an iterative systematic manual review of supervised classifications. After verification of the result of our “habitat model” during year one (of a three year project), we have achieved approximately 90% accuracy for deriving sediment and slightly greater then 80% for our vegetation classes. An important challenge is accurately characterizing the spatial and taxonomic range of vegetation in our classifications that are appropriate to project needs but within the spectral and spatial limits of the imagery. Despite our difficulties with timing the satellite acquisition with Mean Lower Low Water (MLLW) as well as issues with atmospheric effects over time, our semi-automated remote sensing model has great potential to track changes to marsh vegetation at geographic scales relevant for assisting with the larger adaptive restoration effort.

Fuller, C. C., A. van Geen, M. Baskaran, and R. Anima (1999). "Sediment chronology in San Francisco Bay, California, defined by 210Pb, 234Th, 137Cs, and 239,240Pu." Marine Chemistry 64(1-2): 7-27.
Sediment chronologies based on radioisotope depth profiles were developed at two sites in the San Francisco Bay estuary to provide a framework for interpreting historical trends in organic compound and metal contaminant inputs. At Richardson Bay near the estuary mouth, sediments are highly mixed by biological and/or physical processes. Excess 234Th penetration ranged from 2 to more than 10 cm at eight coring sites, yielding surface sediment mixing coefficients ranging from 12 to 170

cm2/year. At the site chosen for contaminant analyses, excess 210Pb activity was essentially constant over the upper 25 cm of the core with an exponential decrease below to the supported activity between 70 and 90 cm. Both 137Cs and 239,240Pu penetrated to 57-cm depth and have broad subsurface maxima between 33 and 41 cm. The best fit of the excess 210Pb profile to a steady state sediment accumulation and mixing model yielded an accumulation rate of 0.825 g/cm2/year (0.89 cm/year at sediment surface), surface mixing coefficient of 71 cm2/year, and 33-cm mixed zone with a half-Gaussian depth dependence parameter of 9 cm. Simulations of 137Cs and 239,240Pu profiles using these parameters successfully predicted the maximum depth of penetration and the depth of maximum 137Cs and 239,240Pu activity. Profiles of successive 1-year hypothetical contaminant pulses were generated using this parameter set to determine the age distribution of sediments at any depth horizon. Because of mixing, sediment particles with a wide range of deposition dates occur at each depth. A sediment chronology was derived from this age distribution to assign the minimum age of deposition and a date of maximum deposition to a depth horizon. The minimum age of sediments in a given horizon is used to estimate the date of first appearance of a contaminant from its maximum depth of penetration. The date of maximum deposition is used to estimate the peak year of input for a contaminant from the depth interval with the highest concentration of that contaminant. Because of the extensive mixing, sediment-bound constituents are rapidly diluted with older material after deposition. In addition, contaminants persist in the mixed zone for many years after deposition. More than 75 years are required to bury 90% of a deposited contaminant below the mixed zone. Reconstructing contaminant inputs is limited to changes occurring on a 20-year time scale. In contrast, mixing is much lower relative to accumulation at a site in San Pablo Bay. Instead, periods of rapid deposition and/or erosion occurred as indicated by frequent sand-silt laminae in the X-radiograph. 137Cs, 239,240Pu, and excess 210Pb activity all penetrated to about 120 cm. The distinct maxima in the fallout radionuclides at 105–110 cm yielded overall linear sedimentation rates of 3.9 to 4.1 cm/year, which are comparable to a rate of 4.5±1.5 cm/year derived from the excess 210Pb profile.

Fuller, H. (2010). Benthic Monitoring, 2009. IEP Newsletter. 23: 2.

Fuller, H., K.Gehrts, D. Riordan, and J. Thompson (2012). The biomass of Corbula and Corbicula in the low salinity zone in August 2011. 2012 IEP Workshop. Lake Natoma Inn, Folsom, CA, Interagency Ecological Program (IEP).
        Did high flow events in the spring of 2011 result in significant changes in the biomass of the invasive bivalves Corbula amurensis and Corbicula fluminea in the low salinity zone (LSZ) in August, relative to previous sampling events?

Long term trends in Corbula abundances at the 2 regular benthic monitoring sites in the Bay zone in August (Figure 2) support the finding of fewer Corbula in the Bay zone in 2011.
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Interestingly,Corbula biomass was not found to be significantly different between sampling events in the Lower Bay zone, another zone with historically high Corbula biomass.
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Corbicula was found much farther west in August 2011 than in previous GRTS events, suggesting its range expands with high freshwater flows

Fung, K. (2010). San Joaquin River Flows, Water Years 2008 and 2009. IEP Newsletter. 23: 2.

Gabet, E. J. (1998). "Lateral migration and bank erosion in a saltmarsh tidal channel in San Francisco Bay, California." Estuaries 21(4B): 745-753.
        Saltmarsh tidal channels have often been recognized as being stable landscape features, despite highly sinuous planforms, severely undercut banks, and high rates of bank erosion. In an effort to solve this paradox, a saltmarsh tidal channel in Chiana Camp Marsh, San Francisco Bay was monitored from March 1995 to March 1996. The short-term rate of bank erosion was measured using erosion pins and found to be 57 plus or minus 10 mm yr super(-1) on the outside banks of meander bends. In addition, a long-term maximum lateral migration rate of 23 plus or minus

23 mm yr super(-1) was estimated from aerial photos, producing a dimensionless channel migration rate (defined as the rate of migration divided by channel width) of 0.5% yr super(-1). The difference in the rates of lateral migration and bank erosion is attributed to the persistence of failed bank material (slump blocks) in the channel. The slump blocks induce sedimentation, protect the banks, and prevent further bank erosion. A published stability analysis method for undercut banks is applied to determine a maximum overhanging width. Using the measured compressive and tensile strengths of rooted bank material, 16.55 plus or minus 1.16 kPa and 2.93 plus or minus 0.71 kPa, respectively, the maximum width of an undercut bank is calculated to be 0.69 m. The average width of slump blocks measured in the field is 0.67 plus or minus 0.25 m. A simple numerical model predicting the rate of lateral migration is derived using the results from the stability analysis and data from sedimentation and erosion pins inserted throughout the channel. This model accurately predicts a rate of 23 plus or minus 3 mm yr super(-1).

Gall, G. A. E., D. Bartley, B. Bentley, J. Brodziak, R. Gomulkiewicz, and M. Mangel (1992). "Geographic variation in population genetic structure of chinook salmon from California and Oregon." U.S. National Marine Fisheries Fishery Bulletin 90(1): 77-100.
We analyzed the protein products of 78 isozyme loci in 37 populations of chinook salmon Oncorhynchus tshawytscha from California and Oregon. Allele frequencies at 47 polymorphic loci revealed substantial genetic variability within the study area. The collections of chinook salmon studied could be differentiated into five major groups located in the following geographical areas: (1) Smith River-Southern Oregon area, (2) Middle Oregon Rivers, (3) Klamath-Trinity Basin, (4) Eel River-California Coastal area, and (5) Sacramento-San Joaquin Basin. Average heterozygosity estimates were lowest in collections from the Klamath-Trinity area and highest in the Oregon populations. Gene diversity analysis indicated that differences among fish within samples accounted for 89.4% of the total diversity, whereas intersample differences accounted for 10.6 %. Estimates of the average level of historical gene flow between populations ranged from 15.57 migrants per generation in the Sacramento-San Joaquin River system to 3.97 in the Klamath-Trinity Basin; an overall estimate of number of salmon exchanging genes between populations per generation was 2.11. Although these data appeared to reflect primarily population structures existing prior to the 20th century, evidence of some effects of hatchery management and transplantations was detected.

Gallagher, S. P. (1993). "Life history variation in the temporary pool snail, Fossaria sonomaensis, in the Northern Sacramento Valley." American Midland Scientist 130(2): 372-385.
The snail Fossaria sonomaensis inhabits temporary pools in the Northern Sacramento Valley. Snails vary in growth rate, fecundity, size and density depending on pool and catchment basin size, pool-floor soil and seasonal variability of flooding. An intensive study of population dynamics in pools, a reciprocal transfer between pools, a laboratory study of growth and fecundity, and a comparison of pool physical factors were undertaken. Snails emerge directly after pool flooding and begin ovipositing. A minimum of 30 days is required for eggs to hatch. Snails collected after aestivation ranged in size from 0.005 g to 0.2 g. Because snails smaller than 0.005 g were observed as pools dried, the smallest size breaking aestivation is the minimum size surviving the summer. The minimum size for reproduction is 0.035 g and the majority of reproductive individuals are in their 3rd season. The survival of reproductive individuals to a 2nd season is advantageous in the unpredictable vernal pool habitat. Variation in population parameters is a result of differences in physical characteristics of pools and phenotypic plasticity. The presence of vernal pool snail populations indicates pools that hold water at least 80 days each year.

Gallagher, S. P., and M.F. Gard (1999). "Relationships between chinook salmon (Oncorhynchus tshawytscha) redd densities and PHABSIM-predicted habitat in the Merced and lower American rivers, California." Canadian Journal of Fisheries and Aquatic Sciences 56(4): 570-577.
An index of chinook salmon (Oncorhynchus tshawytscha) spawning habitat predicted using the physical habitat simulation system (PHABSIM) component of the

instream flow incremental methodology was compared with redd densities and locations for sites in the Merced River, California, during 1996 and with redd numbers in sites in the Merced and Lower American rivers, California, from 1989 through 1996. Predicted weighted useable area (WUA) was significantly correlated with chinook salmon spawning density and location at five of seven sites in the Merced River. At the microhabitat level, in the Merced River during 1996, there was a significant relationship between chinook salmon redd location and predicted WUA. Cells with more WUA in the Merced River tended to have more redds. At the mesohabitat level, there was a significant relationship between redd density and predicted WUA in both rivers. Transect areas in the Merced River with higher predicted WUA had more redds. Sites with higher numbers of redds had more predicted WUA. Significant correlations between predicted WUA and spawning locations increase confidence in the use of PHABSIM modeling results for fisheries management in the Merced and Lower American rivers as well as in other rivers.

Ganju, N. K., N. Knowles, et al. (2008). "Temporal downscaling of decadal sediment load estimates to a daily interval for use in hindcast simulations." Journal of Hydrology (Amsterdam) 349(3-4): 512-523.
In this study we used hydrologic proxies to develop a daily sediment load time-series, which agrees with decadal sediment load estimates, when integrated. Hindcast simulations of bathymetric change in estuaries require daily sediment loads from major tributary rivers, to capture the episodic delivery of sediment during multi-day freshwater flow pulses. Two independent decadal sediment load estimates are available for the Sacramento/San Joaquin River Delta, California prior to 1959, but they must be downscaled to a daily interval for use in hindcast models. Daily flow and sediment load data to the Delta are available after 1930 and 1959, respectively, but bathymetric change simulations for San Francisco Bay prior to this require a method to generate daily sediment load estimates into the Delta. We used two historical proxies, monthly rainfall and unimpaired flow magnitudes, to generate monthly unimpaired flows to the Sacramento/San Joaquin Delta for the 1851-1929 period. This step generated the shape of the monthly hydrograph. These historical monthly flows were compared to unimpaired monthly flows from the modern era (1967-1987), and a least-squares metric selected a modern water year analogue for each historical water year. The daily hydrograph for the modern analogue was then assigned to the historical year and scaled to match the flow volume estimated by dendrochronology methods, providing the correct total flow for the year. We applied a sediment rating curve to this time-series of daily flows, to generate daily sediment loads for 1851-1958. The rating curve was calibrated with the two independent decadal sediment load estimates, over two distinct periods. This novel technique retained the timing and magnitude of freshwater flows and sediment loads, without damping variability or net sediment loads to San Francisco Bay. The time-series represents the hydraulic mining period with sustained periods of increased sediment loads, and a dramatic decrease after 1910, corresponding to a reduction in available mining debris. The analogue selection procedure also permits exploration of the morphological hydrograph concept, where a limited set of hydrographs is used to simulate the same bathymetric change as the actual set of hydrographs. The final daily sediment load time-series and morphological hydrograph concept will be applied as landward boundary conditions for hindcasting simulations of bathymetric change in San Francisco Bay.

Ganju, N. K. and D. H. Schoellhamer (2006). "Annual sediment flux estimates in a tidal strait using surrogate measurements." Estuarine, Coastal and Shelf Science 69(1-2): 165-178.
Annual suspended-sediment flux estimates through Carquinez Strait (the seaward boundary of Suisun Bay, California) are provided based on surrogate measurements for advective, dispersive, and Stokes drift flux. The surrogates are landward watershed discharge, suspended-sediment concentration at one location in the Strait, and the longitudinal salinity gradient. The first two surrogates substitute for tidally averaged discharge and velocity-weighted suspended-sediment concentration in the Strait, thereby providing advective flux estimates, while Stokes drift is estimated with suspended-sediment concentration alone. Dispersive flux is estimated using the product of longitudinal salinity gradient and the root-mean-square value of velocity-weighted suspended-sediment concentration as an

added surrogate variable. Cross-sectional measurements validated the use of surrogates during the monitoring period. During high freshwater flow advective and dispersive flux were in the seaward direction, while landward dispersive flux dominated and advective flux approached zero during low freshwater flow. Stokes drift flux was consistently in the landward direction. Wetter than average years led to net export from Suisun Bay, while dry years led to net sediment import. Relatively low watershed sediment fluxes to Suisun Bay contribute to net export during the wet season, while gravitational circulation in Carquinez Strait and higher suspended-sediment concentrations in San Pablo Bay (seaward end of Carquinez Strait) are responsible for the net import of sediment during the dry season. Annual predictions of suspended-sediment fluxes, using these methods, will allow for a sediment budget for Suisun Bay, which has implications for marsh restoration and nutrient/contaminant transport. These methods also provide a general framework for estimating sediment fluxes in estuarine environments, where temporal and spatial variability of transport are large. (c) 2006 Elsevier Ltd. All rights reserved.

Ganju, N. K. and D. H. Schoellhamer (2009). "Calibration of an estuarine sediment transport model to sediment fluxes as an intermediate step for simulation of geomorphic evolution." Continental Shelf Research 29(1): 148-158.

Modeling geomorphic evolution in estuaries is necessary to model the fate of legacy contaminants in the bed sediment and the effect of climate change, watershed alterations, sea level rise, construction projects, and restoration efforts. Coupled hydrodynamic and sediment transport models used for this purpose typically are calibrated to water level, currents, and/or suspended-sediment concentrations. However, small errors in these tidal-timescale models can accumulate to cause major errors in geomorphic evolution, which may not be obvious. Here we present an intermediate step towards simulating decadal-timescale geomorphic change: calibration to estimated sediment fluxes (mass/time) at two cross-sections within an estuary. Accurate representation of sediment fluxes gives confidence in representation of sediment supply to and from the estuary during those periods. Several years of sediment flux data are available for the landward and seaward boundaries of Suisun Bay, California, the landward-most embayment of San Francisco Bay. Sediment flux observations suggest that episodic freshwater flows export sediment from Suisun Bay, while gravitational circulation during the dry season imports sediment from seaward sources. The Regional Oceanic Modeling System (ROMS), a three-dimensional coupled hydrodynamic/sediment transport model, was adapted for Suisun Bay, for the purposes of hindcasting 19th and 20th century bathymetric change, and simulating geomorphic response to sea level rise and climatic variability in the 21st century. The sediment transport parameters were calibrated using the sediment flux data from 1997 (a relatively wet year) and 2004 (a relatively dry year). The remaining years of data (1998, 2002, 2003) were used for validation. The model represents the inter-annual and annual sediment flux variability, while net sediment import/export is accurately modeled for three of the five years. The use of sediment flux data for calibrating an estuarine geomorphic model guarantees that modeled geomorphic evolution will not exceed the actual supply of sediment from the watershed and seaward sources during the calibration period. Decadal trends in sediment supply (and therefore fluxes) can accumulate to alter decadal geomorphic change. Therefore, simulations of future geomorphic evolution are bolstered by this intermediate calibration step. Published by Elsevier Ltd.

Ganju, N. K., D. H. Schoellhamer, et al. (2005). "Suspended sediment fluxes in a tidal wetland: Measurement, controlling factors, and error analysis." Estuaries 28(6): 812-822.

Suspended sediment fluxes to and from tidal wetlands are of increasing concern because of habitat restoration efforts, wetland sustainability as sea level rises, and potential contaminant accumulation. We measured water and sediment fluxes through two channels on Browns Island, at the landward end of San Francisco Bay, United States, to determine the factors that control sediment fluxes on and off the island. In situ instrumentation was deployed between October 10 and November 13, 2003. Acoustic Doppler current profilers and the index velocity method were employed to calculate water fluxes. Suspended sediment concentrations (SSC) were determined with optical sensors and cross-sectional water sampling. All procedures were analyzed for their contribution to total error in the flux measurement. The

inability to dose the water balance and determination of constituent concentration were identified as the main sources of error; total error was 27% for net sediment flux. The water budget for the island was computed with an unaccounted input of 0.20 m(3) s(-1) (22% of mean inflow), after considering channel flow, change in water storage, evapotranspiration, and precipitation. The net imbalance may be a combination of groundwater seepage, overland flow, and flow through minor channels. Change of island water storage, caused by local variations in water surface elevation, dominated the tidally averaged water flux. These variations were mainly caused by wind and barometric pressure change, which alter regional water levels throughout the Sacramento-San Joaquin River Delta. Peak instantaneous ebb flow was 35% greater than peak flood flow, indicating an ebb-dominant system, though dominance varied with the spring-neap cycle. SSC were controlled by wind-wave resuspension adjacent to the island and local tidal currents that mobilized sediment from the channel bed. During neap tides sediment was imported onto the island but during spring tides sediment was exported because the main channel became ebb dominant. Over the 34-d monitoring period 14,000 kg of suspended sediment were imported through the two channels. The water imbalance may affect the sediment balance if the unmeasured water transport pathways are capable of transporting large amounts of sediment. We estimate a maximum of 29800 kg of sediment may have been exported through unmeasured pathways, giving a minimum net import of 11,200 kg. Sediment flux measurements provide insight on tidal to fortnightly marsh sedimentation processes, especially in complex systems where sedimentation is spatially and temporally variable.

Gard, M. (1997). "Technique for adjusting spawning depth habitat utilization curves for availability." Rivers 6(2): 94-102.

A technique to adjust depth habitat utilization curves for spawning to account for low availability of deep waters with suitable velocity and substrate was evaluated in the Merced and American rivers, California. Habitat use data were used to derive initial habitat utilization curves for depth and were modified by a series of linear regressions to define the relative rate of decline, with increasing depth, of habitat use versus the availability of waters with suitable velocities and substrates. This technique allows the effects of availability on use to be estimated but does not overcorrect for effects of availability. Results suggest that there may be a limitation of depth on pawning separate from availability. Such a limitation would need to be considered in developing spawning habitat suitability curves using a mechanistic model.

Gard, M. (2004). "Interactions between an introduced piscivore and a native piscivore in a California stream." Environmental biology of fishes 71(3): 287-295.

The author quantified microhabitat use and abundance of fishes in the South Yuba River (Nevada County, California) to test the hypothesis that predation by introduced smallmouth bass, Micropterus dolomieu, limits the abundance of native Sacramento pikeminnow, Ptychocheilus grandis. Predation by smallmouth bass appears to be the most likely cause of decreases in native species. Based on microhabitat experiments, competition with juvenile smallmouth bass did not contribute to predation by adult smallmouth bass on native species. The main factors that appear to favor smallmouth bass, with regard to intraguild predation with pikeminnow, are: (1) the smaller size of smallmouth bass at the onset of piscivory; (2) the greater use of cover by juvenile smallmouth bass; and (3) lower microhabitat overlaps of juvenile smallmouth bass with piscivores.

Gard, M. (2010). Monitoring the effectiveness of CVPIA dedicated yield in reducing redd dewatering. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The problem we are trying to solve is quantifying the benefits of using CVPIA dedicated yield to reduce redd dewatering. The approach is to map out the locations of shallow redds, using RTK GPS, in previous two-dimensional hydraulic and habitat sites on the Sacramento and American Rivers and Clear Creek. After we have determined the amount of CVPIA dedicated yield used to reduce redd dewatering and what flows would have been in the absence of CVPIA dedicated yield used to reduce redd dewatering, the locations of the redds are used in the two-dimensional hydraulic and habitat models to predict how many of the redds would have been

dewatered if CVPIA dedicated yield had not been used to reduce redd dewatering. In the first year of monitoring, we located 44 shallow fall-run redds on the Sacramento River and 231 shallow fall-run redds and 35 shallow steelhead redds in the American River. The scientific and management implications of the findings are that the results will inform the benefit of using CVPIA dedicated yield to reduce redd dewatering and thus inform to what extent CVPIA dedicated yield should be used to reduce redd dewatering. The relevance of our findings to Bay-Delta management is that the amount of CVPIA dedicated yield used to reduce redd dewatering directly affects how much CVPIA dedicated yield can be used to reduce Delta exports, since there is a fixed total CVPIA dedicated yield of 800,000 acre-feet. The findings provide insights toward how CVPIA dedicated yield can be better used to provide ecosystem sustainability in the near and long term futures.

Gard, M. and E. Ballard (2003). "Applications of New Technologies to Instream Flow Studies in Large Rivers." North American Journal of Fisheries Management 23(4): 1114-1125.
An acoustic Doppler current profiler, underwater video system, hand-held laser range finder and global positioning receiver were used to collect data for instream flow studies on the Sacramento and lower American rivers in California. The use of the equipment decreased the time required to collect spawning criteria data for Chinook salmon Oncorhynchus tshawytscha in deep water in a given area by a factor of 3.4 and doubled the number of transects that could be modeled with the same budget. With the application of quality control criteria, discharges could be measured with an average accuracy of 2.7% versus gauge data with an accuracy of 5%. The total time required to collect data for two-dimensional habitat sites varied with the length and complexity of the sites, and was equivalent to the total time required for physical habitat simulation (PHABSIM) data collection for shorter sites, and less for longer sites.

Gartner, J. W. (2004). "Estimating suspended solids concentrations from backscatter intensity measured by acoustic Doppler current profiler in San Francisco Bay, California." Marine Geology 211(3-4): 169-187.
The estimation of mass concentration of suspended solids is one of the properties needed to understand the characteristics of sediment transport in bays and estuaries. However, useful measurements or estimates of this property are often problematic when employing the usual methods of determination from collected water samples or optical sensors. Analysis of water samples tends to undersample the highly variable character of suspended solids, and optical sensors often become useless from biological fouling in highly productive regions. Acoustic sensors, such as acoustic Doppler current profilers that are now routinely used to measure water velocity, have been shown to hold promise as a means of quantitatively estimating suspended solids from acoustic backscatter intensity, a parameter used in velocity measurement. To further evaluate application of this technique using commercially available instruments, profiles of suspended solids concentrations are estimated from acoustic backscatter intensity recorded by 1200- and 2400-kHz broadband acoustic Doppler current profilers located at two sites in San Francisco Bay, California. ADCP backscatter intensity is calibrated using optical backscatterance data from an instrument located at a depth close to the ADCP transducers. In addition to losses from spherical spreading and water absorption, calculations of acoustic transmission losses account for attenuation from suspended sediment and correction for nonspherical spreading in the near field of the acoustic transducer. Acoustic estimates of suspended solids consisting of cohesive and noncohesive sediments are found to agree within about 8-10% (of the total range of concentration) to those values estimated by a second optical backscatterance sensor located at a depth further from the ADCP transducers. The success of this approach using commercially available Doppler profilers provides promise that this technique might be appropriate and useful under certain conditions in spite of some theoretical limitations of the method.

Gartner, J. W., R. T. Cheng, et al. (1997). Near bottom velocity and suspended solids measurements in San Francisco Bay, California. Environmental and coastal hydraulics: protecting the aquatic habitat. S. S. Y. Wang and T. Carstens, ASCE. 2: 1090-1095.

Gartrell, G. (1993). "Predicting water quality at municipal water intakes - Part 1: application to the southern Sacramento-San Joaquin Delta." Hydraulic Engineering 1993 1: 815-820.

Gartrell, G., R. Denton, L. Orloff, and D.M. Sereno (2010). Historical context for Delta flow and salinity standards. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The watershed of the Sacramento–San Joaquin Delta provides drinking water for more than 23 million Californians as well as irrigation water for millions of acres of agriculture in the Central Valley. The Delta itself is a complex estuarine ecosystem, with populations of many native species now in serious decline. Successful revival and sustainability of the Delta ecosystem requires an understanding of the conditions under which native species evolved. Our detailed review of monitoring data, scientific reports, and modeling analyses establishes an historical record of flow and salinity conditions in the Western Delta and Suisun Bay before European settlement through to the present day. While it is not feasible to remove all human interference from the system, this review of natural variability provides context for discussion of further modifications to Delta flows.

Gartrell, G., and D. Sereno (2010). Salinity conditions in the Bay and Delta: natural variability and anthropogenic influence. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Salinity in the San Francisco Bay and Delta, where saline ocean waters meet fresh riverine waters, is affected by both natural events and human activities. Paleoclimatic evidence, obtained from proxy information such as tree rings and sediment deposits, provides a history of hydrology and salinity conditions starting well before human influence, but continuing through the 20th Century. Examination of paleoclimatic studies, together with modern direct instrumental observations, reveals natural variability and the effect of human interference. Historical salinity information is recorded in situ in the sediments and determined by quantification and taxonomic identification of diatoms, plant seeds and roots, and plant pollen, as well as measurement of peat carbon isotope ratios. Sediment cores at multiple locations in the Bay and Delta reveal site-specific variability, yet many reconstructions indicate that salinity increased abruptly about 100 years ago, reaching or exceeding salinity levels at any other time in the 2,500 years of reconstructed records. Furthermore, although multi-century dry periods are evident in Bay sediments, these long dry periods are not seen in Delta sediments, indicating that salinity did not intrude as far into the Delta during past droughts as it has during the last 100 years. This suggests a change in spatial salinity gradient characteristics, and is possibly due to the effect on salinity intrusion of the vast tidal marshes that existed in the Bay and Delta until the late 19th and early 20th centuries. This change in salinity distribution is further examined using the earliest salinity measurements taken within the Bay and Delta (starting in 1908) to provide a finer temporal resolution and additional insight into the effect of anthropogenic modifications. Comparing time periods with similar hydrology, during the early 1900’s, fresh water was present farther downstream and persisted for a longer period during the spring and early summer.

Gartside, E. D. (1995). Growth of larval Pacific herring in San Francisco Bay. Biology, San Francisco State University.

Gartz, R. G., L. W. Miller, et al. (1999). "Measurement of larval striped bass (Morone saxatilis) net avoidance using evasion radius estimation to improce estimates of abundance and mortality." Journal of Plankton Research 21: 561-580.

Net avoidance rate increases as a function of larval striped bass size. This causes under-estimation of abundance and overestimation of mortality rate. We modeled net avoidance by assuming that fish avoid the net by swimming a radial distance at a right angle to the net axis. This distance, the evasion radius, was estimated by comparing the calculated densities of striped bass larvae from a series of paired tows involving a large and a small net. Iteration and solution models were used to estimate the evasion radius for each millimeter size group of fish in order to estimate the actual density in the environment. Avoidance of the nets increased with fish length. The ratio of actual density in the environment to the measured density in the small net was used to adjust abundances measured in our ichthyoplankton surveys. After adjusting for net avoidance, mortality rates of striped bass larvae from the Sacramento-San Joaquin Estuary were reduced by 10% compared to the unadjusted rates.

Gates, V. L., and R.S. Tjeerdema (1993). "Disposition and biotransformation of pentachlorophenol in the striped bass (Morone saxatilis)." Pesticide Biochemistry and Physiology 46(2): 161-170.
The disposition and biotransformation of pentachlorophenol (PCP, a general biocide) were determined in the striped bass (Morone saxatilis), an anadromous fish that annually spawns in the San Francisco Bay-Delta region of California. Using a modified flow-through exposure system, striped bass (n = 6) were individually exposed to 60 μg/liter of [U-14C]PCP in seawater for 24 hr to determine bioconcentration and tissue distribution; while three individuals were removed for analysis, the remaining three were exposed to clean seawater for an additional 24 hr to allow depuration of retained residues, which were quantified by tissue digestion and liquid scintillation counting (LSC). Excreted residues were collected on XAD-4 resin and identified and quantified using high-pressure liquid cochromatography, fraction collection, and LSC. The 24-hr total concentration factor (similar to a bioconcentration factor but including both PCP and any metabolites) ranged from 134.0 to 189.5, and individual tissue concentrations ranged from 534.2 nmol/g in the hean to 33.3 nmol/g in skeletal muscle; owing to its large mass, skeletal muscle retained the highest fraction of total residues (54.7%). During the 24-hr recovery period, striped bass depurated 36.4% of retained residues. PCP was excreted mainly unchanged (71.5%); however, significant amounts of pentachlorophenylsulfate (20.3%), pentachlorophenyl-β-D-glucuronide (7.0%), and tetrachloro-p-hydroquinone (1.2%) were also produced.

Geen, A., S. N. Luoma, et al. (1992). "Evidence from Cd/Ca ratios in foraminifera for greater upwelling off California 4,000 years ago." Nature 358(6381): 54-56.
Upwelling of nutrient-rich Pacific deep water along the North American west coast is ultimately driven by the temperature difference between air masses over land and over the ocean. The intensity of upwelling, and biological production in the region, could therefore be affected by anthropogenic climate change. Examination of the geological record is one way to study the link between climate and upwelling. Because Pacific deep water is enriched in cadmium, dissolved cadmium concentrations in coastal water off central California reflect the intensity of upwelling. By demonstrating that the Cd/Ca ratio in the shell of a benthic foraminifer, Elphidiella hannai , is proportional to the Cd concentration in coastal water, we show here that foraminiferal Cd/Ca ratios can be used to detect past changes in mean upwelling intensity. Examination of a sediment core from the mouth of San Francisco Bay reveals that foraminiferal Cd/Ca decreased by about 30% from 4,000 years ago to the present, probably because of a reduction in coastal upwelling.

Gehrts, K. A. (2002). Water Year Hydrologic Classification Indices for the Sacramento and San Joaquin Valleys. IEP Newsletter. 15: 2.

Gehrts, K. A. (2003). Status and Trends: Benthic Monitoring 2002. IEP Newsletter. 16: 2.

Gehrts, K. A. (2003). Status and Trends: Chlorophyll a and Phytoplankton. IEP Newsletter. 16: 1.

Gehrts, K. A., S. Philippart, and C. Messer (2004). Benthic monitoring. IEP Newsletter. 17: 2.

Gehrts, K. A., S. Philippart, and C. Messer (2004). Status and Trends: Phytoplankton and chlorophyll abundance and distribution in the upper San Francisco Estuary in 2003. IEP Newsletter. 17: 3.
The status and trends of environmental water quality, phytoplankton, zooplankton, and benthos are all monitored through the IEP’s Environmental

Monitoring Program (EMP). The EMP is mandated by the State Water Resources Control Board Water Right decision 1641, which permits the water management and export activities of the State Water Project and the Central Valley Project. Staff from the Department of Water Resources, the US Bureau of Reclamation, Department of Fish and Game, and the US Geological Survey complete all activities associated with the EMP. Monitoring involves the collection of discrete samples each month at established stations, as well as continuous monitoring of water quality conditions at seven shore-based stations.

Gehrts, K. A., D. Riordan, A. Canepa, J. Evans, J. Thompson, and F. Parchaso (2010). Biomass trends in a bivalve at a DWR long term monitoring site in the Sacramento-San Joaquin Delta. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The Department of Water Resources (DWR) conducts a benthic monitoring program and has been doing so for several decades. The monitoring has, historically only yielded abundance and species data. Beginning in January of 2007, an extra benthic sample has been collected during each sampling event. All live clams are removed, measured, weighed and an ash free dry mass was calculated. Regression equations from these samples have been used to predict the biomass for preserved historic samples for the invasive freshwater clam Corbicula fluminea at one of our long-term monthly monitoring sites, D28A (Old River near the mouth of Rock Slough). We have conducted analysis for trends over time and believe that future investigations invasive bivalve population size structure and biomass will yield information about the influence of local habitat characteristics on population density, biomass and grazing potential. This research could also be essential for managers of restoration programs in the Delta by assessing potential constituents that could affect food web mechanics in aquatic habitats.

Geist, J., I. Werner, et al. (2007). "Comparisons of tissue-specific transcription of stress response genes with whole animal endpoints of adverse effect in striped bass (Morone saxatilis) following treatment with copper and esfenvalerate." Aquatic Toxicology 85(1): 28-39
Changes in the gene transcription of stress response genes in resident fish can be powerful biomarkers for the identification of sublethal impacts of environmental stressors on aquatic ecosystems. In this study, we tested the effects of two reference toxicants, copper (Cu) and the pyrethroid insecticide esfenvalerate [(S)-α-cyano-3-phenoxybenzyl-(S)-2-(4-chlorophenyl)-3-methylbutyrate], on lethal (mortality) and sublethal endpoints (growth, swimming behavior, transcription levels of stress response genes) in juvenile (81–90-day-old) striped bass (Morone saxatilis). We established cellular stress response markers for proteotoxicity (HSP70, HSP90), phase I detoxification mechanism (CYP1A1), metal-binding (metallothionein), as well as immune-function and pathogen-defense (TGF-β, Mx-protein, nRAMP). Quantitative real-time TaqMan® PCR was used to examine tissue-specific changes in the transcriptome of liver, spleen, white muscle, anterior kidney and gills after 7-day Cu exposures and 24-h esfenvalerate exposures. On the transcriptome level, exposure to Cu showed strongest effects on the transcription of metallothionein in spleen tissue, causing a 4-fold increase of mRNA at 42 ppb total Cu and a 10-fold increase at 160 ppb Cu. Exposure to Cu also caused significant tissue-specific changes in gene transcription for immune-system related genes. Esfenvalerate exposure had tissue-specific effects on the transcription of HSP70, HSP90 and CYP1A1. The most significant effects were detected in liver tissue after exposure to 0.64 μg/L esfenvalerate. Our results show that the stress response at the transcriptome level is a more sensitive indicator for Cu and esfenvalerate exposures at low concentrations than swimming behavior, growth or mortality. The accuracy of studies on quantitative changes in the transcriptome can benefit from an initial evaluation or the inclusion of several different tissues and the use of multiple housekeeping genes.

Gellerman, H., and S. Ellis (2010). California Department of Fish and Game’s Invasive Species Program. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Ger, K. A., P. Arneson, et al. (2010). "Species specific differences in the ingestion of Microcystis cells by the calanoid copepods Eurytemora affinis and Pseudodiaptomus forbesi." Journal of Plankton Research 32(10): 1479-1484.
Copepod species showed large differences in the ingestion of Microcystis cells, but no difference among microcystin producing (MC+) or lacking (MC−) strains in a short feeding experiment. Differences in selective feeding may allow some copepods to better tolerate Microcystis.

Ger, K. A., S. J. Teh, et al. (2010). "The effects of dietary Microcystis aeruginosa and microcystin on the copepods of the upper San Francisco Estuary." Freshwater Biology 55(7): 1548-1559.
Summary
1. Increasing blooms of Microcystis aeruginosa have unknown impacts on the copepods Eurytemora affinis and Pseudodiaptomus forbesi, which are the dominant zooplankters and key prey species for endangered larval fish in the upper San Francisco Estuary.
2. Laboratory feeding experiments were designed to measure the effect of Microcystis on copepod survival and to distinguish the effects of toxicity and nutrition. In a series of survival tests, copepods were fed a mixed diet of algae plus one of two strains of Microcystis, either producing (MC+) or lacking microcystin (MC−).
3. Microcystis significantly reduced survival even when it was a small proportion of the diet, indicating that toxicity was the major cause of mortality. Contrary to expectation, however, the MC+ strain did not result in higher mortality, suggesting that non-MC metabolites of Microcystis can be toxic to copepods.
4. Across treatments, survival of P. forbesi was greater than that of E. affinis, although the two copepods responded differently to both the ratio and the strain of Microcystis in their food. Survival of P. forbesi was greater on the MC+ strain and was inversely proportional to the ratio of dietary Microcystis (MC+ or MC−). In contrast, survival of E. affinis declined similarly across treatments and was not related to the proportion or strain of dietary Microcystis. Results indicate that the copepod P. forbesi can coexist with Microcystis while the other copepod E. affinis cannot.
5. Regardless of species, dietary Microcystis caused significant mortality to copepods, and it may cause adverse impacts to the potentially food-limited zooplankton community of the San Francisco Estuary. These impacts may not be related to the cellular MC concentration because Microcystis contains other metabolites that negatively affect copepods.

Ger, K. A., S. J. Teh, et al. (2009). "Microcystin-LR toxicity on dominant copepods Eurytemora affinis and Pseudodiaptomus forbesi of the upper San Francisco Estuary." Science of the Total Environment 407(17): 4852-4857.
This study investigates the toxicity and post-exposure effects of dissolved microcystin (MC-LR) on the dominant copepods of the upper San Francisco Estuary (SFE), where blooms of the toxic cyanobacteria Microcystis aeruginosa coincide with record low levels in the abundance of pelagic organisms including phytoplankton, zooplankton, and fish. The potential negative impact of Microcystis on the copepods Eurytemora affinis and Pseudodiaptomus forbesi has raised concern for further depletion of high quality fish food. Response of copepods to MC-LR (MC) was determined using a 48-h standard static renewal method for acute toxicity testing. Following exposure, a life table test was performed to quantify any post-exposure impacts on survival and reproduction. The 48-h LC-50 and LC-10 values for MC were 1.55 and 0.14 mg/L for E. affinis; and 0.52 and 0.21 mg/L for P. forbesi. Copepod populations recovered once dissolved MC was removed and cultures returned to optimal conditions, suggesting no post-exposure effects of MC on copepod populations. Dissolved microcystin above 0.14 mg/L proved likely to have chronic effects on the survival of copepods in the SFE. Since such high concentrations are unlikely, toxicity from dissolved microcystin is not a direct threat to zooplankton of the SFE, and other mechanisms such as dietary exposure to Microcystis constitute a more severe risk.

Gewant, D. S. and S. M. Bollens (2005). "Macrozooplankton and micronekton of the lower San Francisco Estuary: Seasonal, interannual, and regional variation in relation to environmental conditions." Estuaries 28(3): 473-485.
Macrozooplankton and micronekton are intermediaries linking lower trophic

levels (e.g., phytoplankton and mesozooplankton) to higher ones (e.g., fishes and birds). These organisms have not been extensively studied in the San Francisco Estuary (SFE), California. The objective of this study was to determine the distribution and abundance of macrozooplankton and micronekton in the SFE and to describe how these vary seasonally, interannually, and regionally in relation to environmental variables. Water column macrozooplankton and micronekton were sampled monthly from September 1997 to December 2000 at 6 stations spanning North, Central, and South Bays using a Methot Trawl. The macrozooplankton and micronekton in the lower SFE were dominated by 4 fishes and 7 invertebrates that comprised 98% of the total catch. Correspondence analyses revealed 4 groups of species that exhibited similar patterns of distribution and abundance. The assemblages changed between the wet and dry seasons and with distance from the coastal ocean. Based on abundance patterns, the dominant taxa in the lower SFE can be classified as: organisms spawned from common members of neritic assemblages that use mostly North Bay and that are abundant during the dry season (Clupea pallasi, Spirinchus thaleichthys, Porichthys notatus); estuarine-dependent organisms with broad distributions in the estuary year-round (Crangon franciscorum, Crangon nigricauda, Engraulis mordax); resident species remaining within the estuary but occurring mostly in South Bay during the wet season (Palaemon macrodactlyus, Synidotea laticauda, Neomysis kadiakensis); and gelatinous species (Pleurobrachia bachei, Polyorchis spp.) occurring in all three bays with a single peak in abundance in December and January in North and South Bays. The variation in distribution, abundance, and composition of macrozooplankton and micronekton was related to life history strategies, distance from the coastal ocean, and season.

Giddings, J. M., L. W. Hall, et al. (2000). "Ecological risks of diazinon from agricultural use in the Sacramento-San Joaquin River Basins, California." Risk Analysis 20: 545-572.

A probabilistic risk assessment was conducted to evaluate the likelihood and ecological significance of potential toxic effects of diazinon in the Sacramento-San Joaquin system. Diazinon, an organophosphorus insecticide, is used in the Sacramento-San Joaquin River Basin as a dormant spray on almonds and other tree crops, as well as for other agricultural and urban applications. Diazinon and other pesticides have been detected in the Sacramento and San Joaquin Rivers and their tributaries. Diazinon exposure was characterized based on monitoring programs conducted in 1991-94. Diazinon effects were characterized using laboratory toxicity data for 63 species, supplemented by results from field mesocosm and microcosm studies. The assessment addressed the possibility that reductions in invertebrate populations could lead to impacts on species of fish that feed on those invertebrates. The risk assessment concluded that fish in these rivers are not at risk from the direct effects of diazinon in the water. Invertebrates are at greater risk, especially in agriculturally dominated streams and drainage channels during January and February. Cladocerans-including Daphnia magna and Ceriodaphnia dubia, two common bioassay species-are especially sensitive to diazinon and other organophosphates and are likely to be subject to acute toxic effects in some locations at some times. Any ecological damage that may occur, however, is brief and limited to cladocerans. None of the fish species of concern depend on cladocerans as critical components of their diet. Invertebrates that are not affected by observed concentrations of diazinon (copepods, mysids, amphipods, rotifers, and insects) are preferred foods for fish in the Sacramento-San Joaquin system.

Gifford, S. M., G. C. Rollwagen Bollens, et al. (2007). "Mesozooplankton omnivory in the upper San Francisco Estuary." Marine Ecology Progress Series 348: 33-46.

While many studies have examined mesozooplankton feeding in coastal environments,
less attention has been given to this subject in estuaries. We used bottle incubation experiments to
measure the feeding rates of a cladoceran (Daphnia sp.), a calanoid copepod (Acartia spp.), and 2
cyclopoid copepods (Oithona davisae and Limnoithona tetraspina) on the protist plankton (<200 µm)
of Suisun Bay, which is located in the upper San Francisco Estuary (SFE). Nanoplankton (2 to 15 µm)

prey were highly abundant (2000 to 6000 cells ml-1 and 50 to 600 µg C l-1), whereas microplankton (15 to 200 µm) prey were 1 to 2 orders less abundant (10 to 90 cells ml-1 and 1 to 4 µg C l-1). There were few indications that mesozooplankton fed on nanoplankton, while microplankton were often significantly consumed. Daphnia sp. cleared all microplankton prey categories except diatoms at >2 ml predator (pred.)-1 h-1. O. davisae consumed only ciliates in September 2004, while in November 2004 it cleared both ciliates and diatoms at similar rates (0.8 ml pred.-1 h-1). L. tetraspina cleared only aloricate ciliates and flagellates (0.8 to 1.0 ml pred.-1 h-1). Acartia spp. had the highest clearance rates on diatoms of all the predators examined (mean <1.0 ml pred.-1 h-1) but cleared ciliates at even higher rates (>2.0 ml pred.-1 h-1). With respect to biomass ingestion, in every experiment mesozooplankton were found to ingest ciliate carbon at the highest rates (3 to 29 ng C pred.-1 h-1). Our results indicate that while estuarine mesozooplankton are often omnivorous, important species-specific differences exist, and microzooplankton, especially ciliates, are an important component of the upper SFE food web.

Gilbert-Horvath, E. A., J.L. Conrad, and J.C. Garza (2010). Genetic broodstock management in the Russian River: effects on reproductive outcome in endangered coho salmon (Oncorhynchus kirsutch) in California. Annual Meeting of the Society for the Study of Evolution. Portland, OR.

Gilbreath, A., L. McKee, and R. Eads (2010). Concentrations and loads of trace contaminants in the zone 4 line a small tributary, Hayward, California: water years 2007-2010. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Urban runoff has been identified in the total maximum daily loads reports (TMDLs) as a large and potentially controllable source for pollutants of concern (POCs) to San Francisco Bay and these reports encourage further development of loads information from the Bay’s tributaries. To investigate the concentrations and loads of mercury (Hg), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), polycyclic aromatic hydrocarbons (PAHs), organochlorine (OC) pesticides, various metals and other POCs in urban runoff from a small (4.5 sq km) and highly urbanized watershed, storm and base flow samples were collected from a tributary in Hayward called Zone 4 Line A for Water Years 2007-2010. Loads were calculated using linear interpolation, regression with turbidity, or a stratified flow-weighted mean concentration approach. More than 95% of the loads for all contaminants were carried past the sampling location during storm events, along with over 90% of the total discharge. The organic contaminant class with the greatest concentrations and loadings were PAHs, which appear to be mostly associated with automobile and diesel exhaust and brakelining particles. The relative order of loadings for the other organic contaminant classes was OC Pesticides > PBDEs > PCBs. Total mercury was primarily particle-associated and exhibited higher concentrations (1-147 ng/L) than reported in previous studies for both an urban creek in the Sacramento Area (Arcade Creek (90th percentile was approximately 23 ng/L), in Domagalski, 1998) and Sacramento-San Joaquin River flow from the Delta into the Bay (3 – 75 ng/L, in David et al, 2009). The results support the premise that the control of non-point source pollution in highly urban areas of the Bay-Delta ecosystem may reduce loads of bio-accumulative materials such as Hg and PCBs and improve water and sediment quality to help attain beneficial uses for wildlife and humans.

Gingras, M. (1997). Mark/recapture experiments at Clifton Court forebay to estimate pre-screening loss to entrained juvenile fishes: 1976-1993. Sacramento CA, Interagency Ecological Program for the San Francisco Bay/Delta Estuary Technical

Report 55.

Gingras, M. and M. McGee (1997). A telemetry study of striped bass emigration from Clifton Court forebay: implications for predator enumeration and control. Sacramento CA, Interagency Ecological Program for the San Francisco Bay/Delta Estuary Technical Report 55.

Gladding, S., A. Brand, J. Hunt, J. Lacy, and M. Stacey (2010). Measurements of water column and sediment bed interactions in the south San Francisco Bay estuary. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Sediments in the South San Francisco Bay in the bed and in the water column are composed primarily of fine cohesive sediments which are known to be contaminated with a number of new and legacy contaminants. Changes to the South Bay environment, including sea level rise and habitat restoration, have increased concerns that the South Bay may be erosive, introducing additional contaminants into the South Bay ecosystem. Further understanding of the processes that determine the behavior of fine sediments found in the water column and in the bed are needed to evaluate and model how the South Bay will respond to the changing environment. A three week instrument deployment was undertaken in the South Bay to better understand shoal-channel sediment processes at multiple scales. Instruments deployed at ten stations covering roughly two square kilometers measured water velocities, suspended sediment concentrations, salinity and temperature at hourly or shorter intervals. Measurements of the particle size distribution were also made at one location every 12 minutes for the first five days and sediment cores were collected at the beginning and end of the deployment from two locations. From these measurements turbulence and other parameters have also been calculated. Measurements of suspended sediment concentrations during the deployment usually were in the range of 5-50 mg/L on the shoals, with the lowest concentrations observed during spring tides. Episodic events driven by wind waves created peaks around 100 mg/L. Analysis of sediment cores indicated disturbances to the sediment bed of less than 1 cm. Flood tide resuspension of sediments were affected by several factors including strength, duration and direction of the flood tides. Second resuspension events were observed during ebb flood tides, subject to the same factors. Particle size distributions measured during the second resuspension event were different from those measured during the primary resuspension event.

Gleason, E., and S. Martarano (2010). The Bay-Delta Fish & Wildlife Office: Envisioning a healthy and sustainable Bay-Delta ecosystem. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Glenne, B. and R. E. Selleck (1969). "Longitudinal estuarine diffusion in San Francisco Bay, California." Water Research 3: 1-20.

Glibert, P. M. (2010). Changes in the quality and quantity of nutrients over time and the relationships with changes in phytoplankton composition. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Changes in nutrient loads and imbalances in nutrient ratios can have major effects on food webs. The extent to which such changes may have impacted food webs in the San Francisco Estuary over time are of considerable interest due to the relationships between production at the base of the food web and that of higher trophic levels. The following question was addressed using the long-term, 30-year, data from numerous sites in the Bay Delta: how have changes in nutrient loads and forms related to changes in phytoplankton community composition? Changes in the phytoplankton community have occurred over time in terms of species composition and in terms of seasonality of blooms. These changes have also differed over time in the different subembayments of the bay delta system. Different algal functional groups were related with either total load of a particular nutrient form, or to different nutrient ratios. The ratio of inorganic nitrogen:inorganic phosphorus (DIN:DIP) was significantly correlated with the availability of cryptophytes and flagellates; these groups were not abundant when the ratio was above Redfield proportions.

Cyanobacteria, on the other hand, were not well correlated with the ratio of inorganic nitrogen:inorganic phosphorus, and occurred across the spectrum of observed ratios. They were the dominant functional group at high DIN:DIP ratios. The ratio of nitrate:ammonium was related to diatom abundance. These relationships are consistent with nutrient physiological strategies that differ among these algal groups. These findings have management implications because they can help inform the process of nutrient criteria development and can help to identify which forms, as well as loads, are most important to target for nutrient reduction.

Glibert, P. M. (2010). "Long-Term Changes in Nutrient Loading and Stoichiometry and Their Relationships with Changes in the Food Web and Dominant Pelagic Fish Species in the San Francisco Estuary, California." Reviews in Fisheries Science 18(2): 211-232.

Glibert, P. M. (2010). Nutrient-driven food web alterations in the San Francisco Bay Estuary. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Glibert, P. M. (2012). "Ecological stoichiometry and its implications for aquatic ecosystem sustainability." Current Opinion Envir. Sustainability 4: 6.
Aquatic ecosystems are increasingly stressed not only by increased nutrient loads (eutrophication) but also by changing forms and proportions of nutrients. Nutrient enrichment, composition and stoichiometry interact with aquatic food web dynamics in complex ways. Both algal species composition and emergent properties within species change with changing nutrient composition, in turn affecting food webs at all levels. Consumers further regulate – and may even accelerate – discrepancies in nutrient stoichiometry by various feedbacks, release, and recycling pathways. Stoichiometric regulation of aquatic ecosystem structure also occurs at the sediment interface via altered biogeochemical processes and benthic food webs when nutrient composition changes. Thus, multiple feedbacks serve to alter food web structure when nutrient loads are altered. Such feedbacks may also lead to conditions conducive to invasive species and altered stable states as illustrated for the San Francisco Bay Delta and the Rhine River.

Glibert, P. M., D. Fullerton, et al. (2011). "Ecological Stoichiometry, Biogeochemical Cycling, Invasive Species, and Aquatic Food Webs: San Francisco Estuary and Comparative Systems." Reviews in Fisheries Science 19(4): 358-417.

Gold, J. (2010). NOAA mandated fish community and dredge entrainment monitoring in the Delta's federal navigation channels: 2006-2009. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Golet, G., and F. Shilling (2010). An ecological scorecard for Sacramento River terrestrial flora, fauna and channel dynamics. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Assessing the success of restoration projects in achieving ecosystem recovery goals is important both for maintaining support for their continued implementation and to enable learning. On the middle Sacramento River there have been large investments in floodplain restoration over the past twenty years. Associated monitoring studies have taken place, however, to date no systematic characterization of ecosystem response has been completed, nor has there been an integrated reporting methodology developed. In part this is due to the complexity of the task. To assist with this challenge, we are developing an Ecological Scorecard to characterize the status of a subset of Sacramento River ecosystem attributes. Our Scorecard focuses on terrestrial flora, fauna and channel dynamics. For these attributes ecosystem indicators are being selected and performance criteria are being defined. The Scorecard incorporates quantitative data for these indicators, and synthesizes their status into a set of simple categorical ratings of biodiversity health. We view the performance indicators and associated status ratings as hypotheses that may be tested and refined over time. Through repeated measurement, managers can use the Scorecard to determine whether the ecosystem is

responding to conservation investments over time. The Scorecard has the added advantages of providing a rigorous basis for setting conservation objectives, characterizing threats to biodiversity, identifying monitoring and research needs, and communicating management information to non-specialists.

Goman, M. (2001). "Statistical analysis of modern seed assemblages from the San Francisco Bay: applications for the reconstruction of paleo-salinity and paleo-tidal inundation."

The feasibility of developing a seed calibration data set to infer environmental constraints was examined by studying modern seed and vegetation assemblages from 53 stations at three distinct tidal marshes within the San Francisco Bay (salt, brackish and freshwater). Pearson's correlation indicates autochthonous derivation of seeds at the marsh sites. Multivariate statistical analysis of the vegetation and seed data indicates discrete assemblages, which can be used as a proxy for modern salinity and tidal inundation within the estuary. Canonical discriminant analysis indicates that the vegetation and seed assemblages of the three marsh types are statistically distinct. Cluster analysis suggests that marsh vegetation is zoned at the mean higher high water mark at all the sites. The calibration set was then applied to stratigraphic seed data from the estuary to infer changes in paleo-salinity and -tidal inundation during the Holocene. The results of the calibration are compared to earlier reconstructions within the estuary. While the calibrated reconstruction broadly compares to previous reconstructions, a period of inferred lower salinity within the estuary between 3800-2000 cal yr B.P. is calibrated as brackish and not fresh by the calibration model.

Goman, M., R. Malamud-Roam, et al. (2008). "Holocene environmental history and evolution of a tidal salt marsh in San Francisco Bay, California." Journal of Coastal Research 24(5): 1126-1137.

Analyses of three sediment cores collected from a tidal salt marsh located On the western edge of San Pablo Bay in the San Francisco Bay estuary have produced long-term records of late Holocene marsh development. The records from these cores include a suite of elements, organic carbon content, fossil seeds, pollen, and stable carbon isotopes. The stratigraphy indicates fresher water conditions than present between 3400 and 2000 cal YBP. A tidal marsh became established at China Camp after about 2000 cal YBP: between 2000 cal YBP and approximately 700 cal YBP, conditions in the estuary were apparently more saline and variable. This interval was terminated by at least three or possibly five flood events, as evidenced by coarse elastic materials most likely washed down from the surrounding uplands. These floods represent high rainfall events, possibly El Nino years, and occurred during the late Medieval Climatic Anomaly. Greater plant diversity and pollen from some species with low salt tolerance are found in a core collected near the upland edge of the marsh and date to about 200 years ago, suggesting fresher conditions than today. Over the past 50 years, the diversity of marsh vegetation has decreased, and salt tolerant plants (especially Salicornia virginica) have become the dominant species. These changes are likely a result of the impacts of water diversions and upstream dams in the San Francisco Bay watershed.

Goman, M. and L. Wells (2000). "Trends in river flow affecting the northeastern reach of the San Francisco Bay Estuary over the Past 7000 Years." Quaternary Research 54(2): 206-217.

A variety of stratigraphic analyses (particle grain size, iron concentration, loss on ignition, and macrofossils) from sediments obtained from two marsh sites are used to reconstruct a middle to late Holocene record of stream flow into San Francisco Bay. Browns Island, a freshwater/brackish site, is located at the confluence of the Sacramento and San Joaquin rivers and is dominated by stands of Scirpus americanus. Peyton Hill is a brackish site located near Carquinez Straits and is dominated by stands of Scirpus robustus. Twenty-five AMS super(14)C dates provide chronostratigraphic control. During the Holocene, discharge from the Sacramento and San Joaquin rivers was broadly comparable to modern flows; however, an extended period of higher flow began 3800 cal yr B.P. and continued for almost two millennia. At this time Browns Island supported Phragmites communis, a freshwater species, and Peyton Hill supported S. americanus. At least two floods,

recognized by discrete increases in sand and silt, occurred at 3600 and 530 cal yr B.P.

Goman, M. F. (2005). "Discrimination of estuarine marsh subenvironments (San Francisco Bay, California, USA) using a multivariate statistical calibration of abiotic sediment properties." Journal of Sedimentary Research 75(3): 398-408.
Multivariate analysis of a suite of sediment characteristics provides a novel, inexpensive, and time efficient approach to characterizing estuarine depositional subenvironments, especially in the absence of diagnostic microfossils and macrofossils. The development, calibration, and implementation of a statistical model are discussed using data collected from the San Francisco Bay estuary, California. Forty-seven surface sediment samples were collected from three marshes within the San Francisco Bay estuary and from six different subenvironments ranging from tidal salt marsh below mean higher high water (MHHW) to tidal freshwater marsh sediments located above MHHW. Sediment samples were analyzed for percent organic content, percent water content, percent clay content, sediment density, and iron concentration. Standard statistical analysis of the data indicates that changes in sediment characteristics exist within and between the individual marshes; however, individually these characteristics are insufficient to distinguish among marshes and subenvironments. Multivariate analysis therefore is employed to consider the array of sediment characteristics simultaneously. The individual marsh research sites are treated as idealized reference types. The results indicate a strong degree of, and statistically significant, predictive capability. These surface data and analyses are used in the interpretation of stratigraphic cores from three sites in San Francisco Bay. The results using this method were broadly consistent with interpretations using traditional methods; however, this method determined more subtle variability than was previously recognized.

Gosliner, T. M. (1995). "Introduction and spread of Philine auriformis (Gastropoda: Opisthobranchia) from New Zealand to San Francisco Bay and Bodega Harbor." Marine Biology 122(2): 249-255.
Specimens of Philine auriformis have been observed in the southern portion of San Francisco Bay, California, since summer 1992. Specimens from Bodega Harbor were first discovered from intertidal mudflats in April 1994 and probably represent the spread of the San Francisco Bay population to a neighboring estuary. Their numbers have increased steadily and the species is now well established in both estuaries. Examination of the anatomy of specimens collected from California was compared with that described from New Zealand. No significant differences in anatomy were detected in animals from these different localities. It is suggested that the species was introduced into California waters by release of ballast water from international shipping.

Goude, C., and R. Olah (2009). OCAP Biological Opinion. iEP Newsletter. 22: 2.

Gould, A. L. and W. J. Kimmerer (2010). "Development, growth, and reproduction of the cyclopoid copepod Limnoithona tetraspina in the upper San Francisco Estuary." Marine Ecology Progress Series 412: 163-177.
Limnoithona tetraspina is a small cyclopoid copepod that was introduced to the San Francisco Estuary (SFE), USA, in 1993 and became the most abundant copepod species in the low-salinity zone (LSZ). Two previous studies have shown that it feeds only on motile prey, predominantly ciliates. Little is otherwise known of its biology or its role in the estuarine foodweb. We determined development times, growth rates, and fecundity of L. tetraspina from March to August of 2006 and 2007. The mean growth rate of copepodites in both years was 0.03 d-1, which is low relative to values reported for related Oithona spp. Development times were longer in the field than in the laboratory at food saturation, indicating food limitation in the SFE. Mean weight-specific fecundity rate in 2007 was 0.10 d-1, which is twice that of 2006, but within the range of reported values for Oithona spp. Low growth and fecundity rates indicate that the population success of L. tetraspina is due to low mortality. L. tetraspina may avoid certain mortality agents (e.g. visual predation) to which larger copepods are susceptible.

Gray, A., J. Merz, C. Watry, J. Montgomery, and B. Cavallo (2010). The framework for

restoration monitoring at the Merced River Ranch. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The Merced River Ranch (MRR) is a 128-hectare property along the Merced River that was heavily impacted by large-scale aggregate mining activities. In 1998, the California Department of Fish and Game acquired the MRR in the dredger tailings reach of the Merced River with the vision of restoring (i.e., rehabilitate and enhance) channel, floodplain and riparian ecosystem processes and critical habitats for juvenile and adult salmonids. The U.S. Fish and Wildlife Service Anadromous Fish Restoration Program is funding restoration actions to rehabilitate floodplain and channel habitat for juvenile and adult salmonids, and conduct detailed implementation, effectiveness, and validation monitoring. The monitoring program will collect robust data for assessing project success, with potential to inform similar habitat restoration efforts throughout the Central Valley. The monitoring program consists of three conceptual approaches to monitoring: implementation, effectiveness, and validation. The implementation monitoring will determine if the project was installed according to the design standards. The central question is: Was the project implemented according to plan? The effectiveness monitoring will determine if the project was effective in recovering habitat conditions suitable for target species. The central question of effectiveness monitoring is: Was the project effective in meeting its target objectives? The final part of the monitoring program will determine if floodplain restoration projects, like the one at MRR, recover productive habitat for salmonids and riparian vegetation. The central question of validation monitoring is: Are the basic assumptions behind the project conceptual model valid? This question will be addressed with in situ experiments and modeling fish performance based on field-derived data. This presentation describes an overview of the monitoring program and how this monitoring framework helps better understand ecosystem function in restored habitats. This project combines restoration actions, public outreach, and monitoring to better restore habitat in the Merced River, and provide information for other Central Valley rivers.

Greco, S. E. (2010). Habitat sustainability for an endangered songbird: a case study on the Sacramento River. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The California-listed endangered songbird, the western yellow-billed cuckoo (Coccyzus americanus occidentalis), has fewer than 300 individuals remaining statewide according to the most recent census published in 2000. The largest population (about 100 individuals) was found in the riparian forests on the Sacramento River. Large patches of Fremont cottonwood (Populus fremontii) and willow (numerous Salix spp.) are known to be the reproductive and feeding habitat of cuckoos on the river. The reproduction and growth of these plant species are dependent on flooding cycles and new geomorphic substrates created from channel meander processes (erosion and deposition). The vegetation patches have been found to persist in the floodplain between 10-60 years. To better understand the temporal dynamics of the cuckoo’s habitat, a 132 km (80 river miles) study reach on the meandering sector of the Sacramento River was studied to document spatial shifts in cuckoo habitat patches due to hydro-geomorphic processes, vegetation recruitment, and succession over a 35 year period (1952-1987). The co-occurrence of natural vegetation and floodplain age were used to model patches of the cottonwood-willow plant association. Of the 1,664 ha of habitat patches in 1952 only 247 ha (15%) were coincident with 1987. Of the 62 patches delineated for 1987, 17 (27%) emerged anew and independently of the 1952 patches and the remaining 83% formed from shifting adjacent to the patches from 1952. The degree to which the surrogate variable “floodplain age” could predict the presence or absence of cuckoos was tested using four years of observation data (1987-1990); it was found that 75% of patches were correctly predicted for cuckoo presence or absence. The commission error and the omission error were each 12.5%. These findings suggest that long-term sustainability of yellow-billed cuckoo habitat requires on-going river channel meander dynamics to maintain regeneration of large patches of cottonwood-willow plant communities.

Green, S. (2009). Central Valley Chinook Salmon Catch and Escapement. IEP Newsletter. 22: 4.

Greenberg, N., R. L. Garthwaite, et al. (1996). "Allozyme and morphological evidence for a newly introduced species of Aurelia in San Francisco Bay, California." Marine Biology 125(2): 401-410.
The jellyfish Aurelia aurita is usually considered to be a cosmopolitan species. Aurelia medusae observed at Foster City, San Francisco Bay, California, USA, since 1988 are morphologically distinct from Aurelia collected 200 km away in Monterey Bay, but are morphologically similar to aquarium-cultured Aurelia from Japan. They differ consistently in radial canal morphology. In allozyme electrophoresis, significant differences at 12 of 14 polymorphic loci strongly suggest that Aurelia from Foster City and Tokyo Bay belong to one species, while Aurelia from Monterey Bay and Vancouver Island belong to a second species. We propose that Aurelia at Foster City is a recent introduction, possibly from Japan via ships' ballast water. The identities and taxonomic affinities of the two Aurelia defined in this study, and their relationships with the Linnaean A. aurita described from the North Atlantic, will require genetic and morphological study of the currently recognized species A. aurita and A. limbata from several zoogeographical provinces.

Greene, V., L. Sullivan, W.J. Kimmerer, and J. Thompson (2010). Grazing impact of the overbite clam on the microzooplankton assemblage of the San Francisco Estuary. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The overbite clam Corbula amurensis has altered the San Francisco Estuary (SFE) since its introduction in 1986, and its feeding is believed to be the cause of a substantial decline in phytoplankton biomass and in abundance of some zooplankton species. Previous studies have demonstrated high feeding rates of C. amurensis on phytoplankton, bacteria, and copepod nauplii; however, no information is available about grazing on other microzooplankton. Microzooplankton are defined as heterotrophic eukaryotes 20 - 200 µm, which includes copepod nauplii, rotifers, naked ciliates, and tintinnid ciliates. Microzooplankton provide a key link in pelagic foodwebs by consuming phytoplankton and bacteria, and in turn being eaten by mesozooplankton. The primary objectives of this study were to (1) monitor the current abundance of microzooplankton in the Low Salinity Zone of the SFE (salinity < 6) in 2008 and (2) measure consumption rates of C. amurensis on microzooplankton, particularly ciliates. Feeding experiments revealed that the clams cleared 0.5 L ind-1 h-1 of microzooplankton, compared to a clearance rate of 0.2 L ind-1 h-1 of chlorophyll. When extrapolated to field populations of clams, these clearance rates exceed the growth capacity of ciliates. A lack of comparable data from before clams arrived precludes assessment of population changes in the microzooplankton, but at present they must be heavily subsidized from other parts of the estuary. Clams obtained much more of their food from phytoplankton than from the less abundant microzooplankton. This study complements other studies to show that all planktonic functional groups are consumed at high rates by C. amurensis in the SFE.

Greene, V., L. Sullivan, et al. (2011). "Grazing impact of the invasive clam Corbula amurensis on the microplankton assemblage of the northern San Francisco Estuary." Marine Ecology Progress Series 431: 183-193.

Greenfield, B. K. and J. A. Davis (2005). "A PAH fate model for San Francisco Bay." Chemosphere 60(4): 515-530.
A mass balance model was applied to simulate the long-term fate of PAHs in San Francisco Bay. The model treats the Bay as a single box with interacting water and sediment compartments, and includes loading, volatilization, outflow to the ocean, degradation, and burial in deep sediment. The estimated time required for loss of one-half of the mass in the Bay in the absence of loading ranged from 20 d for naphthalene to 5 yr for benzo(b)fluoranthene. Uncertainty analysis using Monte Carlo simulation indicated a high degree of influence and uncertainty for degradation rates, suggesting that improved estimates of degradation would significantly improve the predictive ability of the model. A comparison of model calculations to literature values suggested that external PAH loading to San Francisco Bay was at or above previous estimates of 3600 kg yr super(-1), and that degradation in the Bay was within the range of commonly published estimates for high molecular weight PAHs (4.0 x 10 super(-5) to 4.0 x 10 super(-4) d super(-1)).

Greenfield, B. K., J. A. Davis, et al. (2005). "Seasonal, interannual, and long-term variation in sport fish contamination, San Francisco Bay." Science of the Total Environment 336(1-3): 25-43.

This study documents changes in contamination over time at seasonal, interannual, and decadal time scales for sport fish collected in San Francisco Bay. Samples from seven fish species were prepared according to common consumption practices (muscle fillets either with or without skin) and analyzed for trace metals (mercury and selenium) and trace organochlorine contaminants (PCBs, DDTs, chlordanes, and dieldrin). In 2000, sport fish samples exceeded human health screening values for mercury, PCBs, DDTs, selenium, and dieldrin but did not exceed screening values for chlordanes. On a seasonal time scale, white croaker (Genyonemus lineatus) exhibited significantly lower PCB and lipid concentrations in spring, and a general increase in concentrations in other seasons. When monitoring data were compared among 1994, 1997, and 2000, analysis of variance indicated that concentrations of mercury, PCBs, DDTs, and chlordanes varied significantly among years for several fish species. Interannual variation in DDTs often correlated to changes in sampled fish size or lipid content among years. Interannual variation in mercury and PCBs was evident in striped bass (Morone saxatilis) but absent in shiner surfperch (Cymatogaster aggregata), leopard shark (Triakis semifasciata), and white croaker. The higher interannual variability of striped bass contaminant concentrations may result from migratory behavior and wide home ranges. Chlordanes significantly declined between 1994 and 2000 in white croaker and striped bass. Of the historical data analyzed (1986-2000), only DDT concentrations in white sturgeon (Acipenser transmontanus) showed evidence of a significant decline. Neither PCBs nor selenium showed evidence of a trend in white sturgeon. Between 1970 and 2000, mercury concentrations in striped bass showed no evidence of a trend. The absence of recent trends in mercury may result from the presence of widespread and historic sources, with use reductions occurring in the early 20th century. In contrast to mercury, apparent recent declines in fish tissue DDT and chlordane concentrations may result from use curtailment in the 1970s and 1980s.

Greenfield, B. K., G. S. Siemering, et al. (2007). "Mechanical Shredding of Water Hyacinth (Eichhornia Crassipes): Effects on Water Quality in the Sacramento-san Joaquin River Delta, California." Estuaries and Coasts 30(4): 627-640.

Management actions to control invasive aquatic species can have significant ecosystem-scale effects. We evaluated the water chemistry and nutrient effects of mechanical shredding to control water hyacinth (Eichhornia crassipes) in an agricultural slough and a tidal wetland on the Sacramento-San Joaquin River Delta, California. Shredding was conducted with two types of shredder boats in fall of 2003 and another boat in spring of 2004. Shredding measurably affected water quality, but specific effects varied as a function of shredding site and season. Significant increases were observed for total Kjeldahl nitrogen and total phosphorus for all experiments. Dissolved oxygen effects varied by site, decreasing after shredding at the agricultural slough but increasing at the tidal wetland. The increase in dissolved oxygen likely resulted from tidal incursions from the adjacent river. A year-long time series of dissolved oxygen data indicated a negative relationship between hyacinth abundance and dissolved oxygen concentrations. Hyacinth contained similar tissue concentrations of mercury to underlying sediments, suggesting that plant harvesting could aid mercury remediation efforts. Simple mass calculations indicated that Delta-wide shredding operations could cause between 0.1% and 9.6% increases in the overall abundance of carbon, nitrogen, and phosphorus in the Delta water column. Results suggest that local effects of management actions to control invasive aquatic plants will vary widely as a function of site-specific hydrology, but that estuary-wide effects would be limited.

Greig, C., and M. A. Banks (1999). "Five multiplexed microsatellite loci for rapid response run identification of California's endangered winter chinook salmon." Animal Genetics 30(4): 318-320.

Greig, C., J. M. Robertson, and M. A. Banks (2002). "Rapid PCR-based species tests for threatened sympatric salmonids." Conservation Genetics 3(1): 83-86.

Greig, C., D. P. Jacobson, et al. (2003). "New tetranucleotide microsatellites for fine-scale discrimination among endangered chinook salmon (Oncorhynchus tshawytscha)." Molecular Ecology Notes 3(3): 376-379.
The unambiguous identification of Central Valley spring-run chinook salmon has become imperative since their proposed listing in 1998. The accuracy of methods used to assign individuals to their stock of origin is critical for understanding juvenile migration patterns and determining the success of protection measures. Existing microsatellites discriminate between the endangered winter-run and. other chinook but are insufficient to characterize phylogenetically less distinct runs. Here, we isolated and developed highly variable tetranucleotide microsatellites for the specific goal of increasing discriminatory power among closely related populations, providing a new power towards the reliable differentiation of nonwinter runs.

Greimann, B., and L. Fotherby (2010). Sediment transport and vegetation growth simulation on the San Joaquin River. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Sedimentation and River Hydraulics - One Dimension (SRH-1D) is a one dimensional hydraulic and sediment model used to simulate water surface profiles, sediment transport rates, and erosion and deposition within rivers and canals. There is also a vegetation module that has been built into SRH-1D and this version is called SRH-1DV. The vegetation module tracks the establishment, growth, and survival of various riparian species. The model parameterizes the establishment, growth, and morality using available information for each species. In addition, a companion paper in this conference describes laboratory measurements of cottonwood establishment used to parameterize the model. SRH-1DV has been applied to the San Joaquin River and the flood bypasses from Friant Dam to the confluence with the Merced River to predict future erosion and deposition with and without the San Joaquin River Restoration Program (SJRRP). The model requires several inputs. Cross section information was taken from existing HEC-RAS models of the system. Bed material data was collected from field samples collected throughout the river and bypass system. The daily flows used in the simulations were generated by CALSIM II and a daily time step model. We used the simulated daily flows under with and without SJRRP and we also simulated the erosion and deposition using historical stream gage data. Some of the main concerns of the project include improving and maintaining anadromous fish habitat below Friant Dam and maintaining flood capacity in the project reaches. To this end, we analyzed the mobilization of gravel, analyzed simulated changes to the bed elevations, and also to the riparian vegetation. The reach downstream of Friant is primarily gravel and cobble and we analyzed whether project flows will be able to mobilize this gravel to maintain salmon spawning beds. This reach is already heavily vegetation and does not have significant levee systems. Further downstream, the San Joaquin transitions to a sand bed river and several reaches are without surface water the majority of the year. There is currently little vegetation and the levee system is already stressed. The resupply of base flow to these dry reaches will potentially cause erosion or deposition and increase riparian vegetation density. We use SRH-1DV to assess the erosion or deposition in these reaches and also additional vegetation growth under the San Joaquin River Restoration Project.

Greiner, T. A. (2002). "Records of the Shokihaze goby, Tridentiger barbatus (Gûnther), newly introduced into the San Francisco Estuary." California Fish and Game 88: 68-74.

Grenier, L., and J. Collins (2010). A preliminary framework for monitoring mercury in wetland projects: tidal marsh mercury biosentinels as adaptive management tools. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The potential to increase net methylmercury production and bioaccumulation is a concern for wetland restoration efforts. Wetland projects incorporate different habitat types with distinct food webs and potentially different mercury cycling regimes. Biosentinels can be effective tools for monitoring wetland food webs for mercury exposure and distinguishing differences in methylmercury bioaccumulation in particular geographic areas and food webs, which can in turn, inform managers and

restoration designers in their decision-making about wetland projects. A case study will be presented from the South Bay Salt Pond Restoration Project. South Bay is already impacted by contaminants, and has the largest historic mercury mine in North America, the New Almaden Mine, in its watershed. The South Baylands Mercury Project was a multifaceted effort to evaluate restoration and management options for a complex of ponds at the foot of the New Almaden watershed. Water, sediment, and biota were sampled in a three-year effort to assess changes in mercury bioaccumulation that could occur when the ponds are restored to tidal action and, eventually, to tidal marsh wetlands. This study included the development of biosentinel species that indicated mercury exposure at appropriate spatial and temporal scales, as well as with appropriate habitat specificity to answer the management and restoration-design questions. Probabilistic ambient surveys and site-specific comparisons of biosentinel tissues were completed for key habitats in managed pond and tidal marsh. All scientific results were analyzed within a decision-tree framework to increase the utility of the project for the restoration project managers.

Grenz, C., J. E. Cloern, et al. (2000). "Dynamics of nutrient cycling and related benthic nutrient and oxygen fluxes during a spring phytoplankton bloom in South San Francisco Bay (USA)." Marine Ecology Progress Series 197: 67-80.

Benthic oxygen uptake and nutrient releases of N, P and Si were measured weekly at 2 sites in South San Francisco Bay around the 1996 spring bloom. Exchanges across the sediment-water interface were estimated from whole core incubations performed in the laboratory at in situ temperature and in dark. Fluxes changed significantly on a weekly time scale. Over a period of 15 wk the fluxes of dissolved inorganic N, P and Si ranged from -40 to +200, 0 to 13 and from 30 to 400 mu mol/m super(2)/h respectively. Sediment oxygen demand increased from 10 before to 64 mg O sub(2)/m super(2)/h just after the bloom period. During the bloom, nutrient fluxes represented about 20, 16 and 9% of the Si, P and N requirements for primary production. Before and after the bloom period, Si fluxes contributed up to 30 and > 100% of this requirement and P and N fluxes up to 15 and 50% respectively. Simple empirical models explain most of the spatial-temporal variability of benthic fluxes of Si, P and NH sub(4), (but not NO sub(3)) from 3 predictor variables: sediment porosity, nutrient concentration in bottom waters and chlorophyll content of surficial sediments. These models show that algal blooms influence benthic-pelagic nutrient exchange through 2 processes: (1) depletion of nutrients from the water column (which enhances gradient-driven transports across the sediment-water interface) and (2) sedimentation of labile phytodetritus (which promotes remineralization in or on the surficial sediments). Rates and patterns of nutrient cycling were very different at the shallow and deep study sites, illustrating the challenge of extrapolating measurements of coupled algae-nutrient dynamics to whole ecosystems.

Griffin, F. J., M. R. Brenner, et al. (2004). Survival of Pacific Herring Larvae is a Function of External Salinity. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 37-46.

The importance of salinity to reproduction in Pacific herring Clupea pallasi was examined by studies of survivability at three salinities--4ppt, 16ppt, and 32 ppt--for yolk sac (0-2, 4-6, and 8-10 d posthatch) larvae that were obtained from in vitro fertilizations of gametes from San Francisco Bay fish. Posthatch age (up to 10 d) did not influence sensitivity to salinity. Greater than 68% of low salinity tolerant larvae, in all three posthatch age-groups, survived 7 d in 4ppt and 16ppt, while only 0-31% survived in 32ppt salinity. Salinity during embryonic development and timing within the reproductive season were factors in determining salinity tolerance of larvae. Low salinity tolerant larvae raised through embryonic development in 4ppt or 16ppt had significantly higher mortality in 32ppt than in either 4ppt or 16ppt. Larvae from embryos raised in 32ppt had elevated mortality regardless of larval culture salinity; mortality in these larvae was also greater than that of 4ppt or 16ppt raised larvae that had been kept in the lower salinity waters. Two different regimes of salinity tolerance were observed in larvae during the 2002-2003 reproductive season; cohorts produced during January and February had higher survival in 32ppt than 4ppt, denoted as high salinity tolerant larvae. Those

from March reproduction survived better in 4ppt than 32ppt, denoted as low salinity tolerant larvae. Lastly, salinity tolerances of larvae were similar regardless of whether they were produced from in vitro fertilizations or from natural spawns in San Francisco Bay.

Grimaldo, L., R. E. Miller, et al. (2012). "Fish Assemblages in Reference and Restored Tidal Freshwater Marshes of the San Francisco Estuary." San Francisco Estuary and Watershed Science 10(1).

Grimaldo, L. F., B. Harrell, R. Miller, and Z. Hymanson (1998). Determining the importance of shallow-water habitat in the Delta to resident and migratory fishes: A new challenge for the IEP. IEP Newsletter. 11: 32-34.

Grimaldo, L. F., D. Sweetnam, and B. Ross (1998). Preliminary results on the age and growth of delta smelt (Hypomesus transpacificus) from different areas of the estuary using otolith microstructure analysis. IEP Newsletter. 11: 25-28.

Grimaldo, L. F., and Z. Hymanson (1999). What is the impact of the introduced Brazilian Waterweed Egeria densa to the Delta Ecosystem? IEP Newsletter. 12: 43-45.

Grimaldo, L. F., R.E. Miller, and C. Peregrin (2000). Examining the relative predation risks of juvenile chinook salmon in shallow water habitats of the central Delta: the effect of submerged aquatic vegetation on predation risk. IEP Newsletter. 13: 57-61.

Grimaldo, L. F. (2004). Diet and carbon sources supporting fishes from open-water, edge and SAV habitats in restored freshwater wetlands of the San Francisco Estuary, San Francisco State University.

Grimaldo, L. F., R.E. Miller, C.M. Peregrin, and Z.P Hymanson (2004). Spatial and temporal distribution of ichthyoplankton in three habitat types of the Sacramento-San Joaquin Delta. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi. Bethesda, Maryland, American Fisheries Society. Symposium 39: 81–96.

We examined the spatial and temporal variability of native and alien ichthyoplankton in three habitat types (marsh edge, shallow open-water, and river channel) in one reference and three restored marshes in the Sacramento–San Joaquin Delta, California, during 1998 and 1999. More than 6,700 fish embryos and 25,000 larvae represented by 10 families were collected in 240 tows during the 2-year study. Overall, the assemblage was dominated by alien fishes, but natives were more abundant during winter and spring, whereas aliens were more abundant during summer. Overall abundance was highest in marsh edge habitats, suggesting that this habitat provides favorable larval rearing habitats for many fishes. The reference marsh was dominated by alien species making it difficult to assess whether it had attributes that promoted use by native fish. Ichthyoplankton abundance varied comparably at restored sites of similar configuration. The restored site, with minimal tidal exchange and greater lower trophic productivity, supported the highest densities of alien fish. We conclude that restoration projects in this region of the estuary must consider the potential impacts of alien fishes on natives and evaluate strategies designed to improve recruitment success of native fishes. Specifically, we suggest that restored wetlands that offer only winter and spring inundation periods may provide maximum benefits to natives while limiting access by many alien fishes regardless of specific habitat-use requirements.

Grimaldo, L. F., T. Sommer, et al. (2009). "Factors Affecting Fish Entrainment into Massive Water Diversions in a Tidal Freshwater Estuary: Can Fish Losses be Managed?" North American Journal of Fisheries Management 29(5): 1253-1270.

We examined factors affecting fish entrainment at Califomia's State Water Project and Central Valley Project, two of the largest water diversions in the world. Combined, these diversions from the upper San Francisco Estuary support a large component of the municipal and agricultural infrastructure for California. However, precipitous declines in the abundance of several estuarine fish species, notably the threatened delta smelt Hypomesus transpacificus, have generated major

concern about entrainment as a possible cause of the declines. We examined a 13-year data set of export pumping operations and environmental characteristics to determine factors affecting entrainment (as indexed by salvage at fish screens) and the potential for manipulation of these factors to improve conditions for fish. Entrainment of three migratory pelagic species-delta smelt, longfin smelt Spirinchus thaleichthys, and striped bass Morone saxatilis-was primarily determined by the seasonal occurrence of particular life stages close to the export facilities. We also found that the direction and magnitude of flows through the estuary and to the export facilities were reasonable predictors of pelagic fish entrainment. Entrainment of resident demersal species (prickly sculpin Cottus asper and white catfish Ameiurus catus) and littoral species (Mississippi silverside Menidia audens and largemouth bass Micropterus salmoides) was not explained by diversion flows, although large numbers of individuals from these species were collected. Our study suggests that entrainment of pelagic species can be effectively reduced by manipulating system hydrodynamics.

Grimaldo, L. F., A. R. Stewart, et al. (2009). "Dietary segregation of pelagic and littoral fish assemblages in a highly modified tidal freshwater estuary." Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1(1): 200-217.

Estuarine food webs are highly variable and complex, making identification of their trophic pathways difficult. Energy for the food web of the San Francisco Estuary is thought to be based largely on in situ phytoplankton production, but little attention has been paid to littoral habitats, where other energy sources may be important. We analyzed the stomach contents of over 960 juvenile fishes and the stable carbon and nitrogen isotope ratios of these fishes and their potential food resources in pelagic and littoral habitats from the tidal freshwater area of the estuary. The mixing model IsoSource was used to examine energy sources important to consumers. Our results show evidence of two predominant food web pathways. Pelagic fishes and some littoral fishes showed strong dependence on a zooplankton-phytoplankton trophic pathway. However, the majority of fishes in littoral habitats had diets and carbon isotope ratios consistent with energy arising from submerged aquatic vegetation and epiphytic macroalgae. IsoSource revealed that the overall majority of nutrition of littoral fishes originated from consumption of grazer amphipods. Examining both stable isotopes and stomach contents allowed us to identify a food web with contributions to resident fishes that had been previously underestimated in the estuary. This study provides insight to how estuarine food webs have changed over the last few decades and highlights why the functions of habitats must be understood for effective restoration planning.

Griscom, S. B., N. S. Fisher, et al. (2000). "Geochemical Influences on Assimilation of Sediment-Bound Metals in Clams and Mussels." Environmental Science and Technology 1: 91-99.

A series of experiments was performed to evaluate the extent to which Cd, Co, Ag, Se, Cr, and Zn bound to sediments with different geochemical properties could be assimilated by the mussel Mytilus edulis and the clam Macoma balthica. Oxidized and reduced radiolabeled sediments were fed to suspension-feeding animals, the depuration patterns of the individuals were followed by gamma -spectrometry, and the assimilation efficiencies (AEs) of ingested metals were determined. AEs from geochemically diverse sediments typically varied less than 2-fold and ranged from 1% for Cr to 42% for Zn. Metals were assimilated from anoxic sediment by both animals; Ag, Cd, and Co AEs in M. balthica were 9-16%, 2-fold lower than from oxic sediment, but in M. edulis AEs were about two times greater from anoxic sediment for all metals but Ag. For oxic sediment, Cd and Co AEs in M. edulis decreased 3-4-fold with increased sediment exposure time to the metals with smaller but significant effects also noted for Zn and Se but not Ag. A less pronounced decrease in AE for M. balthica was evident only after 6 months exposure time. Sequential extractions of the oxidized sediments showed a transfer of metals into more resistant sediment components over time, but the rate did not correlate with a decrease in metal AEs. Comparing the two bivalves, TOC concentrations had an inconsistent effect on metal AEs. AEs of metals from bacteria-coated glass beads were slightly higher than from humic acid-coated beads, which were comparable with whole-sediment AEs. There was correspondence of AE with desorption of Ag, Cd, Co, and Se (but not Zn) from sediments into pH 5 seawater, measured to simulate the gut pH of these bivalves. The

results imply that metals associated with sulfides and anoxic sediments are bioavailable, that the bioavailability of metals from sediments decreases over exposure time, that organic carbon content generally has a small effect on AEs, and that AEs of sediment-bound metals differ among species.

Griscom, S. B., N. S. Fisher, et al. (2002). "Kinetic modeling of Ag, Cd and Co bioaccumulation in the clam Macoma balthica: Quantifying dietary and dissolved sources." Marine Ecology Progress Series 240: 127-141.
A biokinetic model was used to better understand Ag, Cd and Co concentrations in a population of the clam Macoma balthica in San Francisco Bay. Model parameters included laboratory-derived uptake- and loss-rate constants from food and water and field measurements of metal concentrations in food, overlying water and oxidized pore water. Parameters used in modeling were taken from recent studies of metal influx from dissolved sources and metal assimilation from ingested sediment, and from laboratory experiments and field measurements in this study. Assimilation efficiencies from surface sediments ranged from 12 to 22% for Ag, 6 to 13% for Cd and 8 to 20% for Co. Assimilation efficiencies from phytoplankton were higher than metal assimilation efficiencies from sediment, ranging from 36 to 42% for Ag, 47 to 55% for Cd and 27 to 33% for Co. Influx of dissolved metals from overlying water increased with increasing ambient concentration, with uptake-rate constants for Ag (0.34 l/g/d) about an order of magnitude higher than for Cd and Co. Influx-rate constants for Ag and Cd from oxidized pore water were comparable to overlying water-rate constants, whereas the rate constant for Co influx from oxidized pore water was 3 times lower than that from overlying water. Efflux rates of all metals out of the clams ranged from 1 to 3%/d. To estimate the potentially bioavailable fraction of particle-bound metals, assumed to be the metal bound to particle surfaces, mean metal concentrations in shale were subtracted from metal concentrations in total sediment digestions. Metal accumulation was modeled for clams that were assumed to be surface deposit-feeding and those that were filter-feeding. By adding uptake from food (surface sediment or phytoplankton) and from dissolved sources (oxidized pore water or overlying water), the modelpredicted ranges of concentrations of Ag, Cd and Co in deposit-feeding clams are shown to be directly comparable to tissue concentrations in field-collected clams from San Francisco Bay. Thus, it appears that the parameters experimentally derived for M. balthica are applicable to field conditions and that the model can account for the major processes governing metal concentrations in these clams. Further, through modeling, ingested sediment was shown to be a major source for Ag and Cd under all realistic environmental conditions, but Co accumulation was principally from the dissolved phase.

Grober, L., A. Ballard, P. Crader, C. Foe, M. Gowdy, D. La Brie, B. Leidigh, M. Mahaney, D. Riddle, and L. Sharkey (2010). Delta flow criteria: regulatory agency synthesis of the science. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Senate Bill 1, enacted on November 12, 2009, added the Sacramento-San Joaquin Delta Reform Act of 2009 to the California Water Code. The Act requires the State Water Board to develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. In August 2010 the State Water Board considered adopting a staff report that contains recommended delta flow criteria, and considers the volume, quality, and timing of water necessary for the Delta ecosystem under different conditions. The staff report reviews existing water quality objectives and uses the best available scientific information in determining the flow criteria. The staff report also reviews the utility of adaptive management and considers short versus long-term flow needs.

Gross, E. S. (2010). Delta smelt entrainment estimated by 3D particle tracking with vertical migration behavior. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Gross, E. S., W.J. Kimmerer, and M.L. MacWilliams (2010). Particle tracking based estimates of recruitment of organisms from the coastal ocean into the low-salinity zone of the San Francisco Estuary. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Abundance or survival of several estuarine species in the San Francisco Estuary is positively related to the position of 2 psu salinity at the bed, known as X2 (Jassby et al. 1995). One of several proposed mechanisms for the observed fish-X2 relationships (Kimmerer 2002),is based on transport processes. In particular, for species that are found near the bed and recruit from the ocean (i.e., starry flounder and bay shrimp), increased gravitational circulation with seaward X2 may result in more rapid landward transport and retention of organisms in their low-salinity rearing habitat. If mortality is lower in the low-salinity zone than during transport, an increased probability of movement up the estuary and faster transport into the low-salinity zone would result in higher survival and subsequent abundance. To investigate this hypothesis, we used the three-dimensional TRIM3D hydrodynamic model and FISH-PTM particle tracking model to estimate recruitment of negatively buoyant particles from the coastal ocean into the low-salinity zone of the San Francisco Estuary. The estimated number of negatively buoyant particles that reached the low-salinity zone increased with increased Delta outflow (decreased X2). In addition, negatively buoyant particles arrived in the low-salinity zone sooner as Delta outflow increased, because of faster transport and reduced distance to travel. These findings support the proposed fish-X2 mechanism.

Gross, E. S., J. R. Koseff, et al. (1999). "Evaluation of adective schemes for estuarine salinity simulations." Journal of Hydraulic Engineering 125(1): 32-46.
Several advective transport schemes are considered in the context of two-dimensional scalar transport. To review the properties of these transport schemes, results are presented for simple advective test cases. Wide variation in accuracy and computational cost is found. The schemes are then applied to simulate salinity fields in South San Francisco Bay using a depth-averaged approach. Our evaluation of the schemes in the salinity simulation leads to some different conclusions than those for the simple test cases. First, testing of a stable, but nonconservative Eulerian-Lagrangian scheme does not produce accurate results, showing the importance of mass conservation. Second, the conservative schemes that are stable in the simulation reproduce salinity data accurately independent of the order of accuracy of each scheme. Third, the leapfrog-central scheme was stable for the model problems but not stable in the unsteady, free surface computations. Thus, for the simulation of salinity in a strongly dispersive setting, the most important properties of a scalar advection scheme are stability and mass conservation.

Gross, E. S., J. R. Koseff, et al. (1999). "Three-dimensional salinity simulations of south San Francisco Bay." Journal of Hydraulic Engineering 125(11): 1199-1209.
A conservative transport method and a two-equation turbulence closure model are added to an established three-dimensional hydrodynamic model. The resulting model is applied to simulate the development of the salinity field in South San Francisco Bay. All model parameters in the salinity simulation are identical to those used in a model calibration in which the model is shown to reproduce current meter data accurately. The 64-day time period studied is characterized by low freshwater input. During this period, the observed salinity data is reproduced well by the model. Because no model parameters are adjusted, the salinity simulation is considered to be a verification of the model. Once the model is verified, it is used to explore the importance of stratification and baroclinic pressure gradients on long-term transport. It is concluded that, under conditions of moderate density gradients, the density-driven flow and mild periodic stratification that results have a significant effect on scalar transport.

Gross, E. S., M. L. MacWilliams, et al. (2010). "Three-dimensional modeling of tidal hydrodynamics in the San Francisco Estuary." San Francisco Estuary and Watershed Science 7(2).
Simulations of circulation in the San Francisco Estuary were performed with the threedimensional
TRIM3D hydrodynamic model using a generic length scale turbulence closure. The model was calibrated to reproduce observed tidal elevations, tidal currents, and salinity
observations in the San Francisco Estuary using data collected during 1996-1998, a period of
high and variable freshwater flow. It was then validated for 1994-1995, with

emphasis on spring
of 1994, a period of intensive data collection in the northern estuary. The model predicts tidal
elevations and tidal currents accurately, and realistically predicts salinity at both the seasonal and
tidal time scales. The model represents salt intrusion into the estuary accurately, and therefore
accurately represents the salt balance. The model's accuracy is adequate for its intended purposes
of predicting salinity, analyzing gravitational circulation, and driving a particle-tracking model.
Two applications were used to demonstrate the utility of the model. We estimated the components of the longitudinal salt flux and examined their dependence on flow conditions, and
compared predicted salt intrusion with estimates from two empirical models.

Grossinger, R., A. Whipple, D. Rankin, and J. Collins (2010). Historical Delta habitat mosaics: Conceptual models for building a diverse and resilient future Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The historical Delta supported large and diverse communities of native plants and animals, including a majority of the State's migratory birds and anadromous fishes. But there has been relatively little research into how this support was distributed within the Delta. Since the advent of Euro-American settlement, much of the historical understanding of the spatial and temporal distribution of Delta habitats has been forgotten. But, this understanding can be recovered. By synthesizing the available historical record through conceptual models and GIS, we are beginning to learn how the Delta looked and functioned prior to significant modification. Useful data are provided by sources such as federal General Land Office surveys, engineering and property maps, Mexican land-grant cases, early aerial photography, and 19th century textual accounts. We find that the historical Delta was spatially very complex, with a variety of subsystems distinguished by unique habitat mosaics, the composition of which varied along identifiable physical gradients, especially topography, tidal range, and freshwater input. These mosaics include dense channel networks occupying low tidal elevations as well as high marsh ecotones merging into seasonal wetlands and oak savanna. Alkali meadows, small ponds, and tule patches characterized the South Delta, while perennial floodplain marshes, large ponds, and riparian gallery forests were more prominent in the North Delta. Ecological function can be inferred from these reconstructed mosaics through expert interpretation across many scientific disciplines. As expected, the complexity of each mosaic and their diversity supported an unusually rich endemic flora as well as large and diverse communities of resident and migratory wildlife. Furthermore, the historical reconstructions are beginning to reveal how physical processes that controlled the mosaics were distributed within the Delta, and where the processes might be nurtured or restored. This information will be important for designing realistic ecosystem targets for contemporary and projected future Delta conditions.

Guarini, J. M., J. E. Cloern, et al. (2002). "Microphytobenthic potential productivity estimated in three tidal embayments of the San Francisco Bay: A comparative study." Estuaries 25(3): 409-417.

In this paper we describe a three-step procedure to infer the spatial heterogeneity in microphytobenthos primary productivity at the scale of tidal estuaries and embayments. The first step involves local measurement of the carbon assimilation rate of benthic microalgae to determine the parameters of the photosynthesis-irradiance (P-E) curves (using non-linear optimization methods). In the next step, a resampling technique is used to rebuild pseudo-sampling distributions of the local productivity estimates; these provide error estimates for determining the significance level of differences between sites. The third step combines the previous results with deterministic models of tidal elevation and solar irradiance to compute mean and variance of the daily areal primary productivity over an entire intertidal mudflat area within each embayment. This scheme was applied on three different intertidal mudflat regions of the San Francisco Bay estuary during

autumn 1998. Microphytobenthos productivity exhibits strong (ca. 3-fold) significant differences among the major sub-basins of San Francisco Bay. This spatial heterogeneity is attributed to two main causes: significant differences in the photosynthetic competence (P-E parameters) of the microphytobenthos in the different sub-basins, and spatial differences in the phase shifts between the tidal and solar cycles controlling the exposure of intertidal areas to sunlight. The procedure is general and can be used in other estuaries to assess the magnitude and patterns of spatial variability of microphytobenthos productivity at the level of the ecosystem.

Guerin, M., and J. DeGeorge (2010). Experience modeling turbidity in the Sacramento-San Joaquin Delta for the 2009-2010 winter season. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

With funding from the Metropolitan Water District of Southern California (MWD) and in collaboration with DWR Operations and Maintenance (O&M) staff, Resource Management Associates (RMA) has developed a 2-D turbidity modeling protocol for short-term forecasting. Starting in December 2009, many new real-time turbidity monitoring stations became available in the Delta, providing a rich data set for developing model boundary conditions and evaluating the performance of turbidity predictions. Using O&M’s DSM2 flow and salinity forecast boundary conditions as a starting point, flow boundary conditions for the Sacramento and San Joaquin Rivers and for the Yolo boundary were refined using forecast conditions from the California-Nevada River Forecasting Center (CNRFC). A simple methodology was developed for forecasting 50% and 90% exceedance values for turbidity boundary conditions at the Sacramento and San Joaquin boundaries. The initial application of a simple turbidity model based on exponential decay gives reasonable results throughout much of the Delta, however, comparison of model results to the extensive observed data set reveals several factors that should be included in a more comprehensive model including: wind-driven resuspension in open water areas; turbidity loading from local rain; ungaged inflows particularly in the Eastern Delta; and settling and resuspension in channels with low net velocity. Overall, the results indicate that measured turbidity will be better approximated by a full suspended sediment model with meteorological inputs for local precipitation and wind, particularly if flow can be measured more accurately during and shortly after storm events.

Gunther, A. J., J. A. Davis, et al. (1999). "Long-term Bioaccumulation Monitoring with Transplanted Bivalves in the San Francisco Estuary." Marine Pollution Bulletin 38(3): 170-181.

The California State Mussel Watch and the Regional Monitoring Program for Trace Substances have conducted biomonitoring for trace elements and organic contaminants in the San Francisco Estuary using transplanted bivalves (Mytilus californianus, Crassostrea gigas, and Corbicula fluminea). Significant declines ($p < 0.01$) in contaminant concentrations in M. californianus for the period 1980-1996 were observed for PCBs, p,p'-DDE, cis-chlordane, dieldrin, and Ag, while a significant increase was observed for Cr ($p < 0.05$). Certain limitations of the "mussel watch" approach are illustrated by examining data on survival, body condition, and contaminant uptake, including the inability of the technique to predict accumulation of mercury and selenium at higher trophic levels in the ecosystem. These results indicate that biomonitoring using transplanted bivalves, when part of a consistently supported long-term program, can produce valuable data on the spatially and temporally averaged abundance and distribution of certain contaminants in coastal ecosystems.

Guo, Y. C., S. Krasner, S. Fitzsimmons, and C. DiGiorgio (2010). Occurrence, fate and transport of emerging contaminants in the Sacramento-San Joaquin Delta. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The Sacramento-San Joaquin Delta is a major drinking water source for California. Agricultural activities are prevalent in the Delta. In addition, there are nine wastewater treatment plants (WWTPs) that discharge into the Delta. The Delta’s fragile ecosystem raises concern about water quality issues, including the occurrence of chemicals of emerging concern (CECs), such as pharmaceuticals and

personal care products, from municipal and industrial wastewater discharges and agricultural activities. Recent studies have reported the occurrence worldwide of CECs in WWTP effluents and receiving surface waters, in some cases at levels sufficient to affect aquatic organisms. The objective of this study was to evaluate the occurrence, fate and transport of CECs in the Delta. Samples were collected at the following locations: (1) treated effluent from one WWTP; (2) upstream and downstream locations of several WWTPs; (3) an urban run-off site; and (4) an agricultural drainage site. A suite of more than forty CECs were analyzed. Extensive quality assurance and quality control procedures were applied to ensure that the data obtained were accurate and precise. The most frequently detected analytes were carbamazepine (anti-convulsant), diuron (herbicide), sulfamethoxazole (antibiotic), caffeine (stimulant), primidone (anti-convulsant), and tris(2-chloroethyl)phosphate (TCEP, flame retardant), which were present at ng/L levels. In addition, the fate and transport of these CECs were evaluated. The results can be used by the waste and drinking water industries, watershed and regulatory agencies, and fish and game department for risk assessment, future water resource planning, pollution prevention programs, and public communication.

Haefner, J. W. and M. D. Bowen (2002). "Physical-based model of fish movement in fish extraction facilities." Ecological Modelling 152: 2-3.

Fish collection or diversion facilities are structures designed to remove fish from a channel where they may be endangered from pumps, power plants, or irrigation systems. The Tracy Fish Collection Facility in the Central Valley of California (USA) collects endangered and economically important species before they can enter the Delta Mendota Canal. We describe the structure, sensitivity, and preliminary validation of a model that moves fish through this louver-type fish collection facility. The model is individual-based and moves fish subject to fundamental physical forces in the flowing medium and simple obstacle avoidance behaviors. Fluid dynamics are obtained by solving the Navier-Stokes equations. The primary model output is the salvage efficiency of the facility design. Monte Carlo simulation showed that the mean salvage efficiency is within the variability of field estimates. The most sensitive variables of the model are the initial cross-channel position of the fish and its initial energy reserves. The implications of our results for future collection facility designs are discussed.

Hager, S. W., and L.E. Schemel (1992). "Sources of nitrogen and phosphorus to northern San Francisco Bay." Estuaries and Coasts 15(1): 40-52.

We studied nutrient sources to the Sacramento River and Suisun Bay (northern San Francisco Bay) and the influence which these sources have on the distributions of dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) in the river and bay. We found that agricultural return flow drains and a municipal wastewater treatment plant were the largest sources of nutrients to the river during low river flow. The Sutter and Colusa agricultural drains contributed about 70% of the transport of DIN and DRP by the river above Sacramento (about 20% of the total transport by the river) between August 8 and September 26, 1985. Further downstream, the Sacramento Regional Wastewater Treatment Plant discharged DIN and DRP at rates that were roughly 70% of total DIN and DRP transport by the river at that time. Concentrations at Rio Vista on the tidal river below the Sacramento plant and at the head of the estuary were related to the reciprocals of the river flows, indicating the importance of dilution of the Sacramento waste by river flows. During very dry years, elevated DIN and DRP concentrations were observed in Suisun Bay. We used a steady-state, one-dimensional, single-compartment box model of the bay, incorporating terms for advection, exchange, and waste input, to calculate a residual rate for all processes not included in the model. We found that the residual for DIN was related to concentrations of chlorophyll a (Chl a). The residual for DRP was also related to Chl a at high concentrations of Chl a, but showed significant losses of DRP at low Chl a concentrations. These losses were typically equivalent to about 80% of the wastewater input rate.

Hager, S. W. (1993). Dissolved nutrient and suspended particulate matter data for the San Francisco Bay estuary, California, October 1988 through September 1991. Menlo Park, CA, US Geological Survey.

Hager, S. W., and L.E. Schemel (1996). Dissolved inorganic nitrogen, phosphorus and silicon in South San Francisco Bay. I. Major factors affecting distributions. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science AAAS: 189-216.

Hair, J. R. (1971). "Upper lethal temperature and thermal shock tolerances of the opossum shrimp, Neomysis awatschensis, from the Sacramento-San Joaquin Estuary, California." California Fish and Game 57: 17-27.

Hall, B., A. Shvidchenko, R. MacArthur, R. Leclerc, B. Cruey, L. Adams (2010). Comprehensive geomorphic and sedimentation analyses of lower Sacramento river shows promise for sediment budget modeling of the Delta. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The sediment budget of the Sacramento and San Joaquin Delta system is required for assessing future adjustments in the morphology of this complex landscape of channels, floodplains, and islands. To better understand implications of the sediment budget on morphology, comparisons of the sediment budget with observed morphological adjustments such as bankline adjustment, channel bed change, and the feedback to channel hydraulics is required to develop reliable forecasting tools for predicting future changes to the sediment budget. Northwest Hydraulic Consultants (NHC) completed a sediment budget analysis of the Delta as part of a comprehensive analysis for subsidence management alternatives on Delta islands (Shvidchenko et al., 2004). This analysis included estimates of both bed material and suspended wash load, and identified pathways of sediment inflow, storage, and outflow. More recently, NHC undertook a systematic analysis of the sediment transport and channel morphology of the Sacramento River system for the Army Corps of Engineers. This study collected and reviewed available historic and present-day data related to geomorphology and sediment transport of the Sacramento River system and assessed implications of channel evolution trends and sediment transport regime on the river as well as sediment delivery to the Delta. A 1-dimensional numerical model of the lower Sacramento River was developed that includes sediment routings through the river channel as well as inflows and diversions to the river from the flood bypass systems. The verified model provides very good agreement to measured sediment discharge loads, bed material gradations, stage-discharge rating shifts, and measured bathymetric changes. The computed sediment yield at the Freeport gaging station shows an excellent correspondence between computed and measured sediment discharge for the 1997-2008 time period. Combining NHC’s Delta sediment budget with this new tool provides a means for linking implications of future river management activities on Delta sedimentation dynamics.

Hall, R. K., P. Husby, G.A. Wolinsky, O. Hansen, and M. Mares (1998). "Site access and sample frame issues for R-EMAP Central Valley, California, stream assessment." Environmental Monitoring and Assessment 51(1-2): 357-367.

The Central Valley of California contains critical habitat for many aquatic and terrestrial biological resources. The purpose of this R-EMAP project was to assess the effects from a highly modified agriculturally dominated landuse area on the aquatic resources of the lower portion of the Central Valley watersheds. The study area is 24,346 mi(2) and comprises the Sacramento Valley and San Joaquin Valley watersheds to the 1,000 ft. elevation contour. Populations of interest are man-made conveyances and wadeable natural streams. There are 40,756 miles of streams and constructed conveyances within the Central Valley as designated by RF3 database. Sample sites were selected to represent 14,399 miles of streams and sloughs, and 16,697 miles of constructed conveyances.

Hall, R. K., A. Olsen, D. Stevens, B. Rosenbaum, P. Husby, G.A. Wolinsky, and D.T. Heggem (2000). "EMAP design and River Reach File 3 (RF3) as a sample frame in the Central Valley, California." Environmental Monitoring and Assessment 64(1): 69-80.

The Central Valley, California, R-EMAP project assessed the effects of highly modified, agriculturally dominated landuse on the aquatic resources of the lower portion of the Central Valley watersheds. The focus of this paper is to assess the utility of the EMAP design and the River Reach File version 3 (RF3) 1:100,000 scale Digital Line Graph (DLG) as a sampling frame. The study area is 34,099 mi2(88,316 km2) and comprises the lower reaches of the Sacramento River and San Joaquin River watersheds to the 1000 ft. (305 m) elevation. Sampling sites are selected using a tessellation stratified design to represent the two main populations of interest: natural streams and man-made waterways. Sites are selected to represent 13,226 miles of streams and sloughs, and 14,648 miles of irrigation canals, ditches and drains. To achieve an approximately equal sample size across stream orders and basins, the sample design was weighted by Strahler order categories to ensure sampling occurred in the higher order streams. Based on office and field reconnaissance, the study provided information on the quality of RF3 as a sampling frame. Site selection using RF3 had a success rate of approximately 44%. The RF3 database has an error rate of approximately 7%. When human influence factors were included, the error rate increased to 16%. There was an 11% error rate when selecting sites for natural streams, and approximately a 14% error rate for man-made waterways. The reconnaissance information indicated that presence or absence of irrigation ditches and return drains depends on changing agricultural uses. Some of the error in the RF3 for natural streams and man-made waterways can be attributed to rapid urban expansion, especially in the San Joaquin basin.

Hallock, R. J., R.F. Elwell, and D.H. Fry Jr. (1970). "Migrations of adult king salmon Oncorhynchus tshawytscha in the San Joaquin Delta; as demonstrated by the use of sonic tags." California Department of Fish and Game Fish Bulletin 151: 8-92.

Each fall, king salmon, Oncorhynchus tshawytscha, bound for the Sacramento and San Joaquin River systems, pass through the Sacramento-San Joaquin Delta. Starting in 1961, salmon runs of the San Joaquin, but not of the Sacramento, suffered a disastrous collapse, probably due to water conditions in the San Joaquin part of the Delta. A partial recovery started in 1964. An annually recurring oxygen block caused by pollution in the south-eastern part of the Delta, plus reversal of direction of flow in all three major north-south channels of the San Joaquin (southern) part of the Delta, were believed responsible for the collapse. In the eastern channel, flow reversal which lasts into the salmon migration period occurs only in exceptionally dry falls such as 1961; in the other channels it occurs annually. Reversal is caused by operation of a 4,600 cfs capacity pumping plant which pulls Sacramento River water south through channels that normally carry San Joaquin water north. From 1964 through 1967, salmon tagged with sonic tags were released in the central part of the Delta to determine their reaction to low oxygen levels and reversed flows. Electronic equipment enabled us to follow tags by boat and to record their movement past fixed points. Salmon avoided water with less than 5 ppm dissolved oxygen by staying farther downstream until the oxygen block cleared. Temperatures over 66° F. had a similar but less sharply defined effect. In 1964, pumped water and partial closure of one major west-flowing channel were used to force extra water through the polluted area and break up the oxygen block. At present pumping rates, this method is practical in dry years, but is not needed in normal or wet years. Relatively few fish used either of two western channels which had reversed flows but would have led them to their destination. The pattern of salmon movement is complicated by a large flow of Sacramento River water which diverts through the Delta Cross Channel and Georgiana Slough and flows successively through the Mokelumne and San Joaquin Rivers and back into the Sacramento. Some Sacramento salmon go upstream by this route. A second large pumping plant (10,000 cfs capacity) has recently been completed, and will greatly increase flow reversal problems until a closed canal system (such as the proposed Peripheral Canal) is used to conduct Sacramento River water to the two large pumping plants.

Hallock, R. J., and H. Rectenwald (1989). Environmental factors contributing to the decline of the winter-run chinook salmon on the upper Sacramento River. Northwest Pacific chinook and coho salmon workshop proceedings. Bethesda, MD, American Fisheries Society: 141-145.

Hallock, R. J., D. A. Vogel, et al. (1982). "The effect of Red Bluff Diversion Dam on the migration of adult chinook salmon, Oncorhynchus tshawytscha, as indicated by radio-tagged fish."

The effect of Red Bluff Diversion Dam (RBDD) on the migration of adult radio tagged chinook salmon, Oncorhynchus tshawytscha, was studied. The total tags available were apportioned to the four runs (fall, late-fall, winter, and spring) in

proportion to the estimated numbers of fish in each run. Delay by radio tagged salmon below the dam ranged from 1 to 40 days and averaged 3.5, 3.9, 11.0,and 18.2 days for fall-, late-fall, spring-, and winter-run fish, respectively. Of the total radio tagged salmon that approached the dam, 63.3% migrated upstream past it and 26.7% backed downstream; 10% were not accounted for. For those radio tagged salmon that passed the dam, delay time immediately below the dam increased with flow. Study results indicate that operation of the dam, rather than flow itself, may be the major contributor to delay below the dam. However, this could not be rigidly tested because we could not alter normal operation of the dam during the study period. Study results also indicated that the relationship of flow past the dam to the time salmon are delayed immediately below the dam may have threshold levels related to the number of dam gates opened. More information on fish passage at high flows and on a greater variety of dam gate openings is necessary to determine more definitively what relationship flow and operation of the dam may have on adult salmon passage.

Haltom, T. C. a. W. E. T. (1993). Estimating Agricultural Ground-Water Pumpage in California. Effluent Use Management, Tucson, AZ, American Water Resources Association.

Hamilton, S. J., and R.H. Wiedmeyer (1990). "Concentrations of boron, molybdenum, and selenium in chinook salmon." Transactions of the American Fisheries Society 119(3): 500-510.

The concentrations of boron, molybdenum, and selenium in young chinook salmon Oncorhynchus tshawytscha were determined in three partial life cycle chronic toxicity studies. In each study, fish were exposed to a mixture of boron, molybdenum, selenate, and selenite in the proportions found in subsurface agricultural drainage water in the basin of the San Joaquin Valley, California. Tests were conducted in well water and in site-specific fresh and brackish waters. No boron or molybdenum was detected in fish exposed to concentrations as high as 6,046 µg boron/L and 193 µg molybdenum/L for 90 d in well water or fresh water; however, whole-body concentrations of selenium increased with increasing exposure concentrations in well water and fresh water, but not in brackish water. Concentrations of selenium in chinook salmon were strongly correlated with reduced survival and growth of fish in well water and with reduced survival in a 15-d seawater challenge test of fish from fresh water. Concentrations of selenium in fish seemed to reach a steady state after 60 d of exposure in well water or fresh water. Fish in brackish water had only background concentrations of selenium after 60 d of exposure, and no effects on survival and growth in brackish water or on survival in a 10-d seawater challenge test were exhibited. This lack of effect in brackish water was attributed to initiation of the study with advanced fry, which were apparently better able to metabolize the trace element mixture than were the younger fish used in studies with well water and fresh water. In all three experimental waters, concentration factors (whole-body concentration/waterborne concentration) for selenium decreased with increasing exposure concentrations, suggesting decreased uptake or increased excretion, or both, of selenium at the higher concentrations.

Hamilton, S. J., and K.J. Buhl (1990). "Safety assessment of selected inorganic elements to fry of chinook salmon (Oncorhynchus tshawytscha)." Ecotoxicology and Environmental Safety 20(3): 307-324.

The acute toxicities of arsenate, arsenite, cadmium, chromate, copper, mercury, silver, vanadium, and zinc were determined, individually and in two environmentally relevant mixtures, to two life stages of chinook salmon in reconstituted fresh and brackish waters that stimulated potential conditions in the San Joaquin Valley, California. The relative individual toxicities of the elements varied over four orders of magnitude; from most toxic to least toxic, the rank order was cadmium greater than copper greater than mercury greater than zinc greater than vanadium greater than arsenite greater than arsenate greater than chromate (no definitive tests for silver). In general, young fish tested in fresh water were more sensitive to the individual elements and the two mixtures than were advanced fry tested in brackish water. A 13-element mixture simulating concentrations in the San Luis Drain had the same toxicity to fish as the same mixture plus selenate and selenite, thus demonstrating that the presence of selenium at its environmental ratio in the mixture contributed no toxicity in short-term tests. As judged by a comparison of the individual acute values for salmon to the expected environmental concentrations in the San Luis Drain, the margins of uncertainty for cadmium and copper in both waters, zinc in fresh water, and mercury in brackish water were less than 100, whereas for the two environmental mixtures the margins were less than 15 in both test waters. These low margins of uncertainty, especially for the mixtures, indicate a high potential for environmental hazard to chinook salmon in the reconstituted waters tested.

Hammersmark, C. T., W. E. Fleenor, et al. (2005). "Simulation of flood impact and habitat extent for a tidal freshwater marsh restoration." Ecological Engineering 25(2): 137-152.

It has been estimated that over 90% of the tidal freshwater wetlands of the Sacramento-San Joaquin Delta region in California, USA, have been leveed, removing them from tidal and floodwater inundation. One alternative for restoration of tidal freshwater marsh ecosystems is to reconnect regions currently managed for agricultural purposes to the adjacent rivers and sloughs. Two elements of such restoration efforts that have not been adequately addressed are the impact that restoration efforts are likely to impose on flood stages, and the extent of various habitat types that may develop. This study tests the hypothesis that habitat restoration and flood mitigation can be compatible. MIKE 11, a one-dimensional, unsteady hydraulic model is used to evaluate the flood stage impacts of five restoration scenarios for the McCormack-Williamson Tract, located in the northern Sacramento-San Joaquin Delta of California, USA. In addition to quantifying flood impacts, model results are used to quantify the volume of tidal exchange, and integrated with GIS to quantify the potential areal extent of subtidal, intertidal, and supratidal habitat zones within the project. The results indicate that the restoration would provide a mosaic of habitat types, and have a minimal adverse impact upon flood stages during a range of flooding conditions.

Hammond, D. E. and C. Fuller (1979). The use of Radon-222 to estimate benthic exchange and atmospheric exchange rates in San Francisco Bay. San Francisco Bay: the Urbanized Estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 213-230.

Hammond, D. E., C. Fuller, et al. (1985). "Benthic fluxes in San Francisco Bay." Hydrobiologia 129: 69-90.

Measurements of benthic fluxes have been made on four occasions between February 1980 and February 1981 at a channel station and a shoal station in South San Francisco Bay, using in situ flux chambers. On each occasion replicate measurements of easily measured substances such as radon, oxygen, ammonia, and silica showed a variability (±1agr) of 30% or more over distances of a few meters to tens of meters, presumably due to spatial heterogeneity in the benthic community. Fluxes of radon were greater at the shoal station than at the channel station because of greater macrofaunal irrigation at the former, but showed little seasonal variability at either station. At both stations fluxes of oxygen, carbon dioxide, ammonia, and silica were largest following the spring bloom. Fluxes measured during different seasons ranged over factors of 2–3, 3, 4–5, and 3–10 (respectively), due to variations in phytoplankton productivity and temperature. Fluxes of oxygen and carbon dioxide were greater at the shoal station than at the channel station because the net phytoplankton productivity is greater there and the organic matter produced must be rapidly incorporated in the sediment column. Fluxes of silica were greater at the shoal station, probably because of the greater irrigation rates there. N + N (nitrate + nitrite) fluxes were variable in magnitude and in sign. Phosphate fluxes were too small to measure accurately. Alkalinity fluxes were similar at the two stations and are attributed primarily to carbonate dissolution at the shoal station and to sulfate reduction at the channel station. The estimated average fluxes into South Bay, based on results from these two stations over the course of a year, are (in mmol m–2 d–1): O2 = –27 ± 6; TCO2 = 23 ± 6; Alkalinity = 9 ± 2; N + N = –0.3 ± 0.5; NH3 = 1.4 ± 0.2; PO4 = 0.1 ± 0.4; Si = 5.6 ± 1.1. These fluxes are comparable in magnitude to those in other temperate estuaries with similar productivity, although the seasonal variability is smaller, probably because the annual temperature range in San Francisco Bay is smaller.

Budgets constructed for South San Francisco Bay show that large fractions of the net annual productivity of carbon (about 90%) and silica (about 65%) are recycled by the benthos. Substantial rates of simultaneous nitrification and denitrification must occur in shoal areas, apparently resulting in conversion to N2 of 55% of the particulate nitrogen reaching the sediments. In shoal areas, benthic fluxes can replace the water column standing stocks of ammonia in 2-6 days and silica in 17-34 days, indicating the importance of benthic fluxes in the maintenance of productivity.
Pore water profiles of nutrients and Rn-222 show that macrofaunal irrigation is extremely important in transport of silica, ammonia, and alkalinity. Calculations of benthic fluxes from these profiles are less accurate, but yield results consistent with chamber measurements and indicate that most of the NH3, SiO2, and alkalinity fluxes are sustained by reactions occurring throughout the upper 20-40 cm of the sediment column. In contrast, O2, CO2, and N + N fluxes must be dominated by reactions occurring within the upper one cm of the sediment-water interface. While most data support the statements made above, a few flux measurements are contradictory and demonstrate the complexity of benthic exchange.

Hammond, J., and T. Griggs (2010). Using long-term monitoring of horticultural performance as a measure of restoration success. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Understanding long-term vegetation performance on habitat restoration projects is critical to effective planning of future projects. The performance period for a restoration project typically lasts from 3-5 years and during this time practitioners are able to monitor plant performance, however they are usually unable to continue monitoring beyond this short time-frame due to funding constraints. Currently, monitoring of restoration that occurs beyond the installation and active management period typically evaluates wildlife use and their associated habitat characteristics, however these measures fail to indicate the horticultural performance of restoration plantings (i.e. did the species we planted persist, did they develop the structure we expected them to). We present preliminary data on a Long-Term Monitoring (LTM) project conducted along the Sacramento River, California that measured horticultural performance of restoration plantings of two age classes (8 and 15 years after the performance period) and on two common soil types (Columbia Fine Sandy Loam and Columbia Silt Loam). Within our sampling categories we investigated plant density, species survivorship, structural measurements of individual species, and Importance Values (I.V.) based on relative density, relative dominance, and relative frequency. We found a decrease in the density (plants per acre) from initial planting to our survey period. We found no significant decrease in the number of species present, though did find that some species, particularly valley oak appear to have lower survivorship in some conditions. There was little difference in the structural measurements for the two soil types. The I.V.'s indicate that community structure after 8 to 15 years is variable, though some patterns exist that will be useful to practitioners to guide future restoration. Our results will help future planning efforts along the Sacramento River by providing practitioners with information on how restoration progresses on a temporal scale. Knowledge on species structure will help in guiding efforts to provide habitat for target wildlife species, or achieve other goals, on a long term scale. Additionally, this initial study provides a baseline that can provide insight on how other ecological conditions (hydrology, fire regime, etc.) might influence the trajectory of restoration.

Hanes, D. M. and P. L. Barnard (2007). "Morphological evolution in the San Francisco Bight." Journal of Coastal Research 1(Special issue 50): 469-473.
San Francisco Bight, located near the coast of San Francisco, USA, is an extremely dynamic tidal inlet
environment subject to large waves and strong currents. Wave heights coming from the Pacific Ocean
commonly exceed 5 m during winter storms. During peak flow tidal currents approach 3 m/s at the Golden Gate,
a 1 km wide entrance that connects San Francisco Bay to the Pacific Ocean. Flow structure in this region varies

markedly spatially and temporally due to the complex interaction by wind, waves and tidal currents. A
multibeam sonar survey was recently completed that mapped in high resolution, for the first time, the bottom
morphology in the region of the ebb tidal delta. This data set includes a giant sand wave field covering an area of
approximately 4 square kilometres. The new survey enables the calculation of seabed change that has occurred in
the past 50 years, since the last comprehensive survey of the area was completed. This comparison indicates an
average erosion of 60 centimetres which equates to a total volume change of approximately 9.2 x 107 m3.
Morphologic change also indicates that flood channels have filled and that the entire ebb delta is contracting
radially

Hansen, L. D., K.J. Maier, and A.W. Knight (1993). "The effect of sulfate on the bioconcentration of selenate by Chironomous decorus and Daphnia magna." Archives of Environmental Contamination and Toxicology 25(1): 72-78.

Agricultural drainage containing high concentrations of selenium (Se) poses a continuing threat to wildlife in California's San Joaquin Valley. Drainage water from this area frequently contains high concentrations of sulfate, which are known to have mediating effects on the bioaccumulation and toxicity of Se in some organisms. It has been proposed that sulfate concentration should be a consideration in determining water quality criteria for Se. As a step toward analyzing the viability of such a plan, this study evaluated the effect of varying sulfate concentration on Se bioconcentration by two aquatic invertebrates. Fourth instar Chironomus decorus and neonate Daphnia magna were exposed, for a 48 h period, to 5.92 and 0.71 mg Se/L, as selenate, respectively. The selenium:sulfur (Se:S) ratio in the dilution waters ranged from 1:0 to 1:480 for C. decorus and 1:3 to 1:240 for D. magna. Increasing sulfate concentrations significantly reduced the accumulation of Se by both organisms. However, D. magna and C. decorus bioconcentrate Se differently at low sulfate concentrations. This difference can be explained by a two permease model for selenate/sulfate absorption. Although this experiment showed that sulfate may reduce selenate bioavailability to aquatic invertebrates, there is no indication that sulfate may completely eliminate selenate absorption. Thus, further research should be performed before sulfate concentration becomes a factor in the determination of water quality standards for selenium.

Hanson, C. H. (2001). Are juvenile chinook salmon entrained at unscreened diversions in direct proportion to the volume of water diverted? Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 331-342.

Mark-recapture experiments were used to test the null hypothesis that juvenile chinook salmon smolts emigrating from the Sacramento River are entrained at unscreened water diversions in direct proportion to the water volume diverted. The experiments were conducted at the RD1004 Princeton Pumping Plant during June 1995, with a similar set of mark-recapture experiments conducted at the RD108 Wilkins Slough diversion. Results of four tests conducted at the RD1004 Princeton Pumping Plant showed an average of 0.05% of the marked salmon being entrained, compared to 1.03% of the Sacramento River flow diverted. Overall results at the RD108 Wilkins Slough diversion showed a similar pattern, with 0.08% of the marked salmon being recaptured compared to 1.1% of the Sacramento River flow being diverted. Based upon results of these tests the null hypothesis was rejected. The percentage of juvenile chinook salmon entrained was more than ten times lower than the corresponding percentage of Sacramento River flow diverted. Results of these tests have implications in the assessment of entrainment mortality of juvenile chinook salmon at unscreened diversions and the calculation of costs and biological benefits for intake screening projects. These study results are limited, however, due to the relatively low percentage of Sacramento River flow diverted during these 1995 tests, the assumption that hatchery-reared, spray-dyed salmon released a relatively short distance upstream of an unscreened diversion are representative of the behavioral patterns and distribution of wild salmon within the Sacramento River, and the size and configuration of water diversions tested.

Harper, E., J. Stella, and A. Fremier (2010). Multiscale validation of a spatially explicit demographic model of Fremont cottonwood on the Sacramento River. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Fremont cottonwood is a foundational species for riparian plant and animal communities of the Sacramento River. Predicting the long-term prospects for restoring and protecting this signature species requires an understanding of the physical and biological mechanisms that drive cottonwood recruitment and survival. Field data and conceptual models have contributed to this understanding, but do not allow long-term quantitative predictions. To address this limitation, we combined a process-based river meander migration model with a model of cottonwood population structure to generate predictions of cottonwood forest dynamics. To ensure that model predictions yielded robust results we (1) conducted a global sensitivity analysis, (2) improved the model based on these results, and (3) validated the model using a multi-scale approach. Our global sensitivity analysis found that uncertainty in the three physical parameter estimates: capillary fringe height, floodplain accretion rate and stage-discharge relationship and their interactions had the greatest influence on model predictions. While we were able to improve estimates of floodplain accretion rate and stage-discharge relationships by incorporating systematic longitudinal variation, we found that predictions of capillary fringe height have a large degree of associated error that is challenging to predict. This variability makes it difficult to accurately predict the specific location of cottonwood stands on a large spatial and temporal scale; however, the model can make large-scale predictions of the total area of cottonwood stands along the reach, and can make reasonable spatially-explicit predictions for areas of known sediment texture. Our coupled modeling approach allows us to predict broad-scale cottonwood patch dynamics to inform restoration efforts and to assess the effects of management decisions including climate change predictions, regulated flow adjustments, and floodplain manipulations.

Harrell, W. C., and T.R. Sommer (2003). Patterns of adult fish use on California's Yolo Bypass Floodplain. 2001 Riparian Habitat and Floodplains Conference Proceedings: California riparian systems: Processes and floodplain management, ecology, and restoration, Riparian Habitat Joint Venture, Sacramento, California

In this paper we describe initial results from a study to examine adult fish diversity, abundance and timing of occurrence in the Yolo Bypass, the largest floodplain of the San Francisco Estuary. A fyke trap was used to capture adult fish between November 1999 and June 2000. We observed over 1,600 individuals representing 19 species including federally listed winter-run and spring-run chinook salmon (Oncorhynchus tshawytscha), splittail (Pogonichthys macrolepidotus) and sport fish such as white sturgeon (Acipenser transmontanus), striped bass (Morone saxatilis) and American shad (Alosa sapidissima) during the sampling period. Flow pulses immediately preceding floodplain inundation apparently triggered upstream movement of a suite of native fish including splittail, Sacramento sucker (Catostomus occidentalis), Sacramento pikeminnow (Ptychocheilus grandis) and Sacramento blackfish (Orthodon microlepidontus). However, we also observed immigration of chinook salmon, white sturgeon, American shad and striped bass during low flow periods, when there was no upstream connection to the Sacramento River. Concurrent screw trap sampling suggested that these migrations resulted in successful spawning of many species including splittail, American shad and striped bass. Our study demonstrates that the Yolo Bypass floodplain represents an important migration corridor and spawning habitat for Delta fish; however, restoration of the migration corridor will improve fish passage to upstream tributaries particularly during low flow periods.

Harrison, L., R.M. Nisbet, K.E. Anderson, and L. Pecquerie (2010). Modeling food delivery dynamics for juvenile salmonids under variable flow regimes. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Traditional approaches for assessing instream flow needs for salmonids have typically focused on the importance of physical habitat in determining fish habitat selection. This somewhat simplistic approach does not account for differences in food delivery rates to salmonids that arise due to spatial variability in river morphology, hydraulics and temporal variations in the flow regime. Explicitly linking how changes in the flow regime influences food delivery dynamics is an important step in advancing process-based bioenergetic models that seek to predict growth rates of salmonids across various life-stages. Here we investigate how food delivery rates for juvenile salmonids vary both spatially and with flow magnitude in a meandering reach of the Merced River, CA. We utilize a two-dimensional (2D) hydrodynamic model and discrete particle tracking algorithm to simulate invertebrate drift transport rates at baseflow and a near-bankfull discharge. Modeling results indicate that at baseflow, the maximum drift density occurs in the channel thalweg, while drift densities decrease towards the channel margins due to the process of organisms settling out of the drift. During high-flow events, typical of spring dam-releases, the invertebrate drift transport pathway follows a similar trajectory along the high velocity core and the drift concentrations are greatest in the channel centerline, though the zone of invertebrate transport occupies a greater fraction of the channel width. Based on invertebrate supply rates alone, feeding juvenile salmonids would be expected to be distributed down the channel centerline where the maximum predicted food delivery rates are located in this reach. However, this behavior is counterintuitive for salmonids and would lead to high energy expenditures in order to maintain feeding position within the high velocity region. Future efforts will focus on integration of food delivery and bioenergetic models to account for conflicting demands of maximizing food intake while minimizing the energetic costs of swimming. Relevance to CALFED goals: The linked modeling framework developed in this study relates to the broad CALFED goal of developing simulation tools that can be used to improve water management strategies throughout the Bay-Delta ecosystem.

Hart, J. (2010). Building a (more) Sustainable Delta: Lessons from plants. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Pre-gold rush Delta plant life contributed to long-term sustainability by forming the basis of primary production and species diversity for the food web; sequestering carbon and capturing sediment that resulted in an accreting land surface elevation concomitant with global seawater rise; and attenuating physical forces such as wave and current energies. These plant resources are now greatly diminished. Replenishing these plant resources are one component for overall restoration needs of the Delta. The appropriate plant species for restoration can be gleaned from descriptions of the original flora and vegetation still extant on remnant habitats, such as in-channel islands and scattered sites that haven't been “reclaimed”. Existing research shows distinctive plant assemblages - freshwater, brackish, and higher salinity suites of characteristic species - that vary by regions of historic salinity zones; by micro-site elevations; and by areal watershed characteristics. These data need to be incorporated into realistic appraisals of overall restoration planning efforts. The role of plants in levee stability needs to be given higher visibility to both ecosystem efforts and to flood control activities. A variety of techniques and approaches include “soft” plantings and brush boxes, to planting techniques compatible with rock revetment, berms, and stone breakwaters. Minimizing risks of flooding and Delta-wide hydrologic “regime changes” can be partially lessened by levee plant restoration and thru re-configuration of internal island levees and plantings. Arresting further island subsidence can be enhanced through gradual replacement of farming on some highly subsided islands with tule restoration. Working with the farming community, through implementation of a carbon credit initiative program will be needed. Incorporating green engineering and sustainable ecosystem management practices will require a cultural shift from a highly reductionist, Cartesian perspective to a more holistic approach.

Hartman, B. and D. E. Hammond (1985). "Gas exchange in San Francisco Bay." Hydrobiologia 129: 59-68.

Hatfield, S. E. (1985). "Seasonal and interannual variation in distribution and population abundance of the shrimp Crangon franciscorum in San Francisco Bay." Hydrobiologia 129: 199-210.

Hayden, M., J.J. Battles, and J.C. Stella (2010). Drivers of pioneer riparian forest establishment within abandoned channel refugia. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Along regulated rivers in the Central Valley of California, cottonwood (Populus) and willow (Salix) trees have experienced significant declines. If senescing stands are not replaced, long-term persistence of these species and the vital ecosystem connections they mediate are threatened. However, pioneer species like cottonwood typically have multiple strategies for persistence, and in meandering rivers, abandoned channels may provide important spatial refugia that serve as an alternate recruitment pathway for woody pioneers. We are testing a conceptual model that links sedimentation and vegetation dynamics within abandoned channels. This model suggests that conditions change through time from a period where abiotic factors are the primary drivers of forest dynamics, to conditions dominated by biotic interactions, particularly competition for light and moisture. In a controlled community competition study along a realistic environmental gradient, we are testing the effects of water availability (mediated by substrate texture) and interspecific competition (grass, sedge, and forb species) on cottonwood seedling growth and survival under constant water table decline. Plant communities were grown in large diameter “rhizopods”–25cm diameter by 120cm deep pots in which the water table can be manipulated. In each treatment, replicated across 7 rhizopods, 350 cottonwood seedlings were tracked, for a total of 4200 seedlings. We expect cottonwood survival and growth to increase with decreasing cover of herbaceous competitors, and to decrease with increasing substrate size due to moisture stress. We expect poorer growth as a result of an interaction between substrate texture (i.e., water availability) and interspecific competitor cover, and hope to confirm whether this is due to above-ground competition for light, below-ground competition for water, or a combination of the two. Understanding the mechanisms that drive establishment of these pioneers within abandoned channels is a key component to improving management and conservation of the riparian corridor at the landscape-scale.

Hazel, C. R. and D. W. Kelley (1966). Zoobenthos of the Sacramento-San Joaquin Delta. Ecological studies of the Sacramento-San Joaquin Delta. J. T. Turner and D. W. Kelley. Stockton, California Department of Fish and Game: 113-131.

He, L., and G. Yip (2010). Development of flow and thermal regimes for spring-run chinook salmon in Clear Creek. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Instream flow and water temperature in Clear Creek, a tributary to the Upper Sacramento River, have changed significantly since the construction of Whiskeytown Dam. Spring-run Chinook salmon (Oncorhynchus tshawytscha) in Clear Creek were extirpated for 30 years until they reappeared in 1999. Although the abundance of spring-run Chinook salmon has been increasing over the last decade, the population is still vulnerable to extirpation from demographic stochasticity. The objective of this study is to develop a flow regime, which integrates the characteristics of stream hydrology and water temperature requirements, to best promote recovery and enhancement of spring-run Chinook salmon populations in Clear Creek. The analysis of pre- and post-dam streamflow data in Clear Creek using the IHA method provided a basis for assessing hydrologic alterations of flow quantity, frequency, timing, and duration. Based on the data analysis, a “natural” flow regime in Clear Creek should include monthly low flows, high-flow pulses, and small floods. The development of a flow regime must also consider the thermal regime, especially during the summer when high water temperatures can be lethal to fish. A regression model was developed to estimate the reservoir release necessary to meet downstream water temperature requirements for spring-run salmon. The final instream flows recommended for Clear Creek considered both flow and thermal regimes. In addition, an adaptive management strategy for implementing the recommended instream flows and assessing the performance of the implementation will be discussed.

Heady, W., M. Workman, and J. Merz (2010). Fine scale movement, life history and survival of wild Oncorhynchus mykiss of the Mokelumne River, CA. 6th Biennial

Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Steelhead, the anadromous life history of Oncorhynchus mykiss are at risk of extinction in Bay-Delta tributaries even when they coexist with rainbow trout, the resident life history. Understanding the conditions that favor anadromy in O. mykiss is important to the maintenance of life history diversity and the recovery of steelhead populations. The fine-scale movement patterns and survival of one hundred thirty wild O. mykiss were monitored using acoustic telemetry in the Lower Mokelumne River in 2007 and 2008. Fish were captured by boat electrofishing and rotary screw traps. After recovering from surgical implantation of Vemco V9 pingers all fish were released at their capture site. Large-scale movement patterns were recorded using stationary tag readers placed throughout the Lower Mokelumne River and the Bay-Delta area. Fine-scale movement patterns were recorded bimonthly using a handheld hydrophone while boating a 39km standardized survey from Camanche Dam, the upstream limit of anadromy to tidal influence. This technique greatly increased our understanding of O. mykiss movement patterns, and strengthened our estimates of survival. Most individuals only moved short distances or not at all. Less than six fish emigrated from the freshwater section of the Mokelumne River each year and only one smolt successfully made it to sea in 2008. There was a strong positive relationship between number of moves per life and mortality in 2007, presumably due to increased risk of predation. Movement across the population peaked February through April and again in August highlighting the importance of providing sufficient flows seasonally to benefit migration. By documenting movement related mortality and low rates of anadromy this study points to current conditions favoring the resident life history in the Mokelumne River. This study also emphasizes the need to investigate management regimes to benefit anadromy and the recovery of steelhead as mandated under the Endangered Species Act.

Healey, M., M. Dettinger, R. Norgaard, D. Jones, J. Machula, R.Ullrey and S. Hatch (editors) (2008). The State of the Bay-Delta Science, 2008. The State of the Bay-Delta Science. M. Healey. Sacramento, CA, CALFED Scence Program: 174.
The State of Bay-Delta Science, 2008 summarizes and synthesizes our current scientific understanding
of the Bay-Delta. Research on the Bay-Delta system increased dramatically with the creation of the
CALFED Bay-Delta Program in 2000 and this new research has both improved our understanding of
how the Bay-Delta functions and has challenged some long-held beliefs about the Bay-Delta. The eight
chapters of this State of Bay-Delta Science report focus on our new understanding of the California Delta
and what it means for policymaking.
The chapters are written by respected scientists from government and academia who are intimately familiar
with the Bay-Delta. Our target audience, however, is not other scientists but managers, policymakers
and interested laypeople. The editorial board has worked hard to ensure that the language of The State of
Bay-Delta Science, 2008 is accessible to an informed, non-technical audience but is still scientifically
accurate. We hope that this volume will become a fundamental reference for all those who are deeply
concerned with the future of the California Delta and its resources. It is also intended to establish a
baseline of scientific understanding that will improve and evolve as research on the Bay-Delta continues.
From time to time the CALFED Science Program will update the State of Bay-Delta Science report so
that it will continue to be an up-to-date reference.

Healey, M. C. (1994). "Variation in the life history characteristics of chinook salmon and its relevance to conservation of the Sacramento winter run of chinook salmon." Conservation Biology 8(3): 876-877.

The highly variable life history of chinook salmon contributes to both the species' resilience and its apparent sensitivity to disturbance. Variation in chinook can be characterized on scales ranging from the geographic range of the species to variation within populations. Over its geographic range chinook are found in two primary forms, stream-type and ocean-type. Each form is widely distributed and is characterized by a different suite of life history characteristics including smolt age, oceanic distribution, run timing, spawning location, age at maturity, and fecundity. Winter run chinook in the Sacramento River appear to have characteristics intermediate between the two widely distributed forms and may represent a third successful suite of life history characteristics, albeit confined to a single river system. Within and among populations of each of these individual forms there is variation in adult and juvenile habitat use, migratory behavior, fecundity, and age at maturity.

Hearn, A., E. Chapman, A.P. Klimley, P. LaCivita, and A. Bremner (2010). Movement of outmigrating salmonid smolts in relation to dredged and dredged material placement sites in the San Francisco Bay Estuary. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
How do salmonid smolts behave during the final phase of their outmigration from the Sacramento River System? Might they be affected by human activities such as dredging or dredged material placement? What routes do they take to the Golden Gate? To what extent do they utilize the shipping channels in comparison to the flats? Are they subjected to “tidal sloshing” once they reach San Pablo Bay? In late January 2009 and 2010 we placed ultrasonic tags in 500 steelhead and 500 late fall Chinook salmon, and released them at Elkhorn Landing, Sacramento. Passive receivers were deployed across sections of the river, and at key dredge and dredged material placement sites throughout the San Francisco Bay Estuary. Our results provide insight into the behavior of this life stage and the potential for interactions with human activities in the area. We found that both species transited the study area from Benicia Bridge to the Golden Gate rapidly (less than 3 days). Transit rates were similar in each reach, and fish displayed “sloshing” behavior in San Pablo Bay, which was correlated with tidal flow. Both species used the channels preferentially, although fish were detected at an array placed in the shallows and at the shallow areas of bridge cross-sections. Exposure at receivers in marinas and other dredged areas was infrequent and for short periods (less than 10 minutes). The purpose of this research is to provide regulatory agencies with technical information with which to make informed resource management decisions.

Heath, A. G., J.J. Cech, L. Brink, P. Moberg, and J.G. Zinkl (1997). "Physiological responses of fathead minnow larvae to rice pesticides." Ecotoxicology and Environmental Safety 37(3): 280-288.
Newly hatched fathead minnow (Pimephales promelas) larvae were exposed for 4 days to two pesticides and ambient receiving waters to simulate conditions in the Sacramento River, California, during the striped bass spawning season which coincides with pesticide use in adjacent rice culture. Carbofuran and molinate were tested at two concentrations: a higher level approximating one-half the LC50and a level much lower that is similar to that seen in the receiving waters of Colusa Basin Drain. Physiological measurements were made immediately after the exposures and again after a 10-day recovery period in noncontaminated waters. These included growth rate, swimming capacity, response to a mild electric shock, upper and lower lethal temperatures, and activity of acetylcholinesterase in whole-body homogenates. The higher concentrations of carbofuran and molinate caused reductions in swimming capacity, an increased sensitivity to the electric shock, and a reduction in upper lethal temperature. Acetylcholinesterase was reduced in those larvae exposed to the higher levels of carbofuran. In general, the lower levels of pesticide exposure caused no measureable effects nor did exposure to water from Colusa Basin Drain.

Heath, A. G., J. J. Cech, et al. (1993). "Sublethal effects of methyl parathion, carbofuran, and molinate on larval striped bass." Water Quality and the Early Life Stages of Fishes 14: 17-28.
In the Sacramento River, California, newly hatched striped bass (Morone saxatilis) larvae typically get exposed to rice pesticides (molinate, carbofuran, methyl parathion) for at least 4 d as they drift to the San Francisco Bay estuary.

This was simulated in the laboratory using individual pesticides and a combination of all three. Concentrations tested were half of the 96-h LC50 values and a lower level, similar to that recorded in the Colusa Basin Drain, a major agricultural return water source. Tests on the larvae were performed immediately after the 4-d exposures and then again after they had been in non-contaminated water for 10 d. The pesticides caused no mortality during exposures but methyl parathion at the higher concentration caused delayed mortality. Sublethal tests performed on the larvae included forced swimming performance, spontaneous activity, acetylcholinesterase (AChE) activity, RNA/DNA ratio, body weight, and several morphometric measures. There was a slight decrease in swimming performance immediately after exposure to parathion at both concentrations and a decrease in AChE activity. After 10 d in clean water there was still a loss of swimming performance and decreased spontaneous activity in those larvae exposed to the higher concentration, and AChE activity failed to recover. Molinate caused decreased swimming performance at the high concentration both immediately after exposure and subsequently. Molinate also caused an inhibition of AChE activity but an apparent stimulation of growth rate. Decreases in AChE activity occurred at the high concentration of carbofuran and in fish exposed to the combined pesticides immediately after exposure, but this inhibition did not persist in the clean water. Each of the three pesticides caused a slight change in body shape resulting in a greater dorsal-ventral dimension but little or no change in length. Combining the pesticides produced a less than additive effect on the measures. Some of the sublethal effects seen might have implications for recruitment of the already declining populations of striped bass.

Hedgecock, D., M.A. Banks, V.K. Rashbrook, C.A. Dean, and S.M. Blankenship (2001). Applications of population genetics to conservation of chinook salmon diversity in the Central Valley. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. Volume 1: 45-70.

Population genetics is playing an increasingly important role in the conservation of salmonid resources in the Pacific Northwest. The National Marine Fisheries Service considers a salmon population worthy of conservation under the U.S. Endangered Species Act if it represents an Evolutionary Significant Unit (ESU), "…a population (or group of populations) that (1) is substantially reproductively isolated from other conspecific population units, and (2) represents an important component in the evolutionary legacy of the species" (Waples 1991, 1995). Genetic data provide an important, though indirect means for establishing the degree of reproductive isolation between conspecific populations. Indeed, numerous studies of electrophoretically detectable protein polymorphisms carried out over the past 30 years on Pacific salmon species have shown that a high degree of spatial substructure and reproductive isolation results from their homing behavior (Utter 1991). With the advent of DNA markers, particularly mitochondrial and microsatellite DNA markers, resolution of reproductively isolated or partially isolated populations has become more precise. Here, we describe progress resolving chinook salmon diversity and stock structure in the Central Valley of California.

Hedgpeth, J. W. (1979). San Francisco Bay - the unsuspected estuary. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, AAAS: 9-29.

Hedrick, P. W., D. Hedgecock, and S. Hamelberg (1995). "Effective population size in winter-run chinook salmon." Conservation Biology: the journal of the Society for Conservation Biology 9(3): 615-624.

Winter-run chinook salmon from the Sacramento River, California, is federally listed as endangered. Since 1989 there has been aprogram to augment the natural population by capturing adults, artificially spawning them, raising tine young and releasing the smolt. Here we estimate the effective population size of these captive-raised fish, the natural run, and the combination of both groups over the three-year period from 1991 to 1993. We find that the most appropriate estimate of the effective population size of the captive-raised progeny is a variance estimate of effective population size standardized so that the number of released smolts returning to spawn was the same as the number of spawners used to produce the smolts originally. We have generated 10,000 random samples to simulate returns from these released progeny. The estimates of the effective population sizes in 1991, 1992, and 1993 were only 7.02, 19.07, and 7.74, respectively. We then determined limits on the effective population size of the natural run based on 0.1 and 0.333 of the run-size estimates. Using estimates of the captive proportion of the run, the minimum estimates of the effective population size of the overall run for the three years were 21.9, 127.3, and 39.0, and the maximum estimates were 61.6, 401.0, and 108.7. It does not appear that the hatchery program has reduced the overall effective population size. The run sizes in each year are extremely low, however, and it is possible that fish will be lost from this run in one of the years in the immediate future, making reestablishment of a healthy run even more difficult.

Hedrick, P. W. (1999). "Perspective: Highly variable genetic loci and their interpretation in evolution and conservation." Evolution 53: 313-318.

Although highly variable loci, such as microsatellite loci, are revolutionizing both evolutionary and conservation biology, data from these loci need to be carefully evaluated. First, because these loci often have very high within-population heterozygosity, the magnitude of differentiation measures may be quite small. For example, maximum GST values for populations with no common alleles at highly variable loci may be small and are at maximum less than the average within-population homozygosity. As a result, measures that are variation independent are recommended for highly variable loci. Second, bottlenecks or a reduction in population size can generate large genetic distances in a short time for these loci. In this case, the genetic distance may be corrected for low variation in a population and tests to detect bottlenecks are advised. Third, statistically significant differences may not reflect biologically meaningful differences both because the patterns of adaptive loci may not be correlated with highly variable loci and statistical power with these markers is so high. As an example of this latter effect, the statistical power to detect a one-generation bottleneck of different sizes for different numbers of highly variable loci is discussed. All of these concerns need to be incorporated in the utilization and interpretation of patterns of highly variable loci for both evolutionary and conservation biology.

Hedrick, P. W., V.K. Rashbrook, and D. Hedgecock (2000). "Effective population size of winter-run chinook salmon based on microsatellite analysis of returning spawners." Canadian Journal of Fisheries and Aquatic Sciences 57(12): 2368-2373.

We previously estimated the predicted effective population size for the endangered winter-run chinook salmon, Oncorhynchus tshawytscha, based on a number of assumptions, including random survival and return of released fish. Here we present data from actual returning spawners, identified to family by microsatellite loci, and calculate the observed effective population size. In 1994 and 1995, the observed effective population sizes were 93.6 and 78.2% of predicted values, respectively, suggesting that the numbers of returning fish were very close to random expectations in 1994 and less close to random in 1995. The ratio of the effective population size to the adult number, Ne/N, was greater than unity for 1994 and approximately 0.5 in 1995. The high ratio in 1994 reflects the success of the breeding protocol to equalize individual contributions and near random returns, while the lower number in 1995 appears to be the result of both less successful equalization and less close to random returns in that year. These findings provide an optimistic outlook for the success of this supplementation program and suggest that the overall effective population size has not been greatly reduced, since returning spawners represent a broad sample of parents and not fish from only a few families.

Hedrick, P. W., D. Hedgecock, S. Hamelberg, and S.J. Croci (2000). "The impact of supplementation in winter-run chinook salmon on effective population size." The Journal of Heredity 91(2): 112-116.

Supplementation of young raised at a protected site, such as a hatchery, may influence the effective population size of an endangered species. A supplementation program for the endangered winter-run chinook salmon from the Sacramento River, California, has been releasing fish since 1991. A breeding protocol, instituted in 1992, seeks to maximize the effective population size from the captive spawners by equaling their contributions to the released progeny. As a result, the releases in

1994 and 1995 appear not to have decreased the overall effective population size and may have increased it somewhat. However, mistaken use of non-winter-run chinook spawners resulted in artificial crosses between runs with a potential reduction in effective population size, and imprinting of the released fish on Battle Creek, the site of the hatchery, resulted in limiting the contribution of the released fish to the target mainstem population. Rapid genetic analysis of captured spawners and a new rearing facility on the Sacramento River should alleviate these problems and their negative effect on the effective population size in future years.

Hedrick, P. W., D. Hedgecock, et al. (1995). "Effective Population-Size in Winter-Run Chinook Salmon." Conservation Biology 9(3): 615-624.

Winter-run chinook salmon from the Sacramento River, California, is federally listed as endangered Since 1989 there has been a program to augment the natural population by capturing adults, artificially spawning them, raising the young, and releasing the smelt. Here we estimate the effective population size of these captive-raised fish, the natural run, and the combination of both groups over the three-year period from 1991 to 1993. We find that the most appropriate estimate of the effective population size of the captive-raised progeny is a variance estimate of effective population size standardized so that the number of released smelts returning to spawn was the same as the number of spawners used to produce the smelts originally. We have generated 10,000 random samples to simulate returns from these released progeny. The estimates of the effective population sizes in 1991, 1992, and 1993 were only 7.02, 19.07, and 7.74, respectively. We then determined limits on the effective population size of the natural run based on 0.1 and 0.333 of the run-size estimates. Using estimates of the captive proportion of the run, the minimum estimates of the effective population size of the overall run for the three years were 21.9, 127.3, and 39.0, and the maximum estimates were 61.6, 401.0, and 108.7. It does not appear that the hatchery program has reduced the overall effective population size. The run sizes in each year are extremely low, however, and it is possible that fish will be lost from this run in one of the years in the immediate future, making reestablishment of a healthy run even more difficult.

Hedrick, P. W., V. K. Rashbrook, et al. (2000). "Effective population size of winter-run chinook salmon based on microsatellite analysis of returning spawners." Canadian Journal of Fisheries and Aquatic Sciences 57(12): 2368-2373.

The predicted effective population size for the endangered winter-run chinook salmon, Oncorhynchus tshawytscha, was previously estimated based on a number of assumptions, including random survival and return of released fish. Data from actual returning spawners, identified to family by microsatellite loci are presented, and the observed effective population size is calculated. In 1994 and 1995, the observed effective population sizes were 93.6 and 78.2% of predicted values, respectively, suggesting that the numbers of returning fish were very close to random expectations in 1994 and less close to random in 1995. The ratio of the effective population size to the adult number, N sub(e)/N, was greater than unity for 1994 and approximately 0.5 in 1995. The high ratio in 1994 reflects the success of the breeding protocol to equalize individual contributions and near random returns, while the lower number in 1995 appears to be the result of both less successful equalization and less close to random returns in that year. These findings provide an optimistic outlook for the success of this supplementation program and suggest that the overall effective population size has not been greatly reduced, since returning spawners represent a broad sample of parents and not fish from only a few families.

Heim, W., M. Stephenson, A. Bonnema, A. Byington, A. Newman, D. Feliz, L. Sousa, and K. Coale (2010). Best management practices to reduce methylmercury concentrations and exports from seasonal wetlands in the Yolo Wildlife Area, California. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

There is widespread mercury contamination in the Sacramento-San Joaquin Delta. The mercury species of greatest concern to human and wildlife health is monomethylmercury (MeHg). There is concern that increasing total acreage of wetlands in the Delta will have the unintended consequence of increasing MeHg contamination. The goal of this study was to develop best management practices (BMPs) to limit MeHg

loads discharged off wetlands in the Yolo Wildlife Area (YWA). Two experiments were conducted: 1) measured MeHg concentrations in seven ponds during seasonal flooding, and 2) measured MeHg as seasonal wetlands were drained into permanent ponds. Results show concentrations of MeHg in most of the seasonal ponds studied have an initial peak occurring in fall followed by a decrease and a leveling off after January. Concentrations are high (6-15 ng/L) relative to supply water indicating seasonal wetlands produce MeHg. Permanent ponds had lower MeHg concentrations than supply water from seasonal wetlands. Reduction in MeHg concentration occurs once tail water from a seasonal wetland enters a permanent pond. Permanent pond S5 received water from a seasonal pond high in MeHg (average 11.3 ng/L) and concentration was reduced by an order of magnitude (average 1.18 ng/L). Permanent ponds acted as treatment ponds and removed an average of 81% of the MeHg that entered the ponds. Further development of a BMP using permanent ponds to treat seasonal pond tail water is warranted from data presented in this study. Several factors in permanent ponds may be important in removal of MeHg and should be investigated to develop the BMP to implementation stage. These factors include pond design, biological communities, photodemethylation, hydraulic residence time, and particle settling. Development of BMPs to reduce MeHg loads from seasonal wetlands is relevant to wetland restorations as they limit an increase in mercury contamination to surrounding waterways.

Heim, W. A., K. H. Coale, et al. (2007). "Spatial and habitat-based variations in total and methyl mercury concentrations in surficial sediments in the San Francisco Bay-Delta." Environmental Science and Technology 41(10): 3501-3507.
Recent studies indicate significant amounts of mercury (Hg) are annually transported into the San Francisco Bay-Delta (Bay-Delta) as a result of historic gold and Hg mining activities. We examined temporal and spatial variation in concentrations of total Hg (Hg-T) and monomethylmercury (MMHg) in surficial sediments of various ecosystem types in the Bay-Delta. We sampled surficial sediments across the Bay-Delta system and found Hg-T sediment concentrations in the central Delta were generally 100-200 ng g(-1) and increased westward through Suisun Bay to 250-350 ng g(-1). MMHg concentrations in the central Delta were between 1 and 3 ng g(-1), while those in sediments in the perimeter waterways and adjacent bays were less than 1 ng g(-1). Six sites were monitored monthly for over a year to identify seasonal changes in Hg sediment concentrations. Hg-T sediment concentrations ranged from 48 to 382 ng g(-1) and varied as a function of location not season. However, MMHg concentrations varied seasonally, increasing from 1 ng g(-1) during winter months to 6 ng g(-1) during spring and summer. Transects conducted at three marshes in the central Delta revealed MMHg sediment concentrations of 4-8 ng g(-1)at the interior and 2 ng g(-1) at the exterior of the marshes. Habitat type was a major factor controlling MMHg concentration and the MMHg to Hg-T ratio in sediments of the Bay-Delta. MMHg was significantly correlated to Hg-T (r (2) = 0.49) in marsh sediments.

Hemmert, J. E. a. C. M. L.-B. (2012). Using Acoustic Telemetry to Identify Predator Habitat and Route Selection of Sub-Adult Striped Bass in the San Francisco Estuary Watershed. 30th Annual Salmonid Restoration Conference April 6, 2012

Hendrix, N., R. Lessard, and R. Hilborn (2010). Winter OBAN: A statistical life-cycle model for winter-run chinook. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Salmonid research in the Bay - Delta has tended to be focused on the controllable freshwater factors that affect salmon run variability, such as flows and diversions, but there has been less emphasis on other sources of variability such as the ocean. We constructed a life-cycle model of winter-run Chinook that accounts for mortality during all phases of the life-history, that estimates model coefficients in a statistical framework, evaluates covariates that may explain dynamic vital rates, and incorporates uncertainty in the model structure and model coefficients (through Bayesian estimation). The model is entitled Oncohynchus Bayesian Analysis (OBAN). Evaluation of multiple anthropogenic and environmental driver variables indicated that temperature in the spawning reaches, minimum flows in the fry rearing reaches, access to Yolo bypass and water exports in the Delta, upwelling dynamics in the Gulf of Farallones, and ocean harvest were able to explain variability in the winter-run Chinook population dynamics. Evaluation of the impact

of the effects indicated that the winter-run abundance is most sensitive to temperatures in the spawning reaches and flows in the fry rearing stage. The sensitivity of the model is somewhat dependent upon the abundance data to which the model was statistically fit. Thus, adult escapement and juvenile counts at Red Bluff Diversion Dam (RBDD) can be used to evaluate the upstream portion of the life-history, whereas the impact of factors occurring after RBDD are less easily identified due to correlation of survival rates in the Delta, Gulf of Farallones, and ocean stages. Such life history models are critical for understanding the factors that have been associated with changes in population abundance historically, and thus form a short list of actions that may lead to population recovery of listed species, such as winter-run Chinook in the Sacramento River.

Henery, R. E., T.R.Sommer, and C.R. Goldman (2010). "Growth and methylmercury accumulation in juvenile chinook salmon in the Sacramento River and it's gloodplain, the Yolo Bypass." Transactions of the American Fisheries Society 139(2): 550-563.

The literature indicates a strong correlation between inundation of previously oxidized soils, as can occur on a floodplain, and increased microbial methylation of mercury. There is special concern over the potential for increased methylmercury levels in the Yolo Bypass, a 24,000-ha floodplain for California’s Sacramento River and its tributaries. The objective of our first study component was to compare methylmercury accumulation between juvenile Chinook salmon Oncorhynchus tshawytscha in the Yolo Bypass and those in the Sacramento River during a winter 2005 flood event. For each location, we tested accumulation in two groups of hatchery Chinook salmon juveniles: (1) free-ranging, coded-wire-tagged fish that were released into the floodplain and river and recaptured by downstream sampling and (2) fish that were reared in enclosures at fixed locations in both the river and floodplain. We found that free-ranging juvenile Chinook salmon in the floodplain accumulated 3.2% more methylmercury per day than did free-ranging fish in the river. However, fish in the floodplain grew 0.7% more per day than fish in the river. Variance in growth and in methylmercury content was significantly higher in the free-ranging fish than in the enclosure-reared fish, suggesting suboptimal rearing conditions in the enclosures. In a second study component, we analyzed methylmercury levels of free-ranging Chinook salmon released in the Yolo Bypass during hydrologically variable years (2001–2003 and 2005); the objective was to determine whether interannual differences in the primary source of floodwater to the Yolo Bypass were associated with different patterns of mercury accumulation in Yolo Bypass Chinook salmon. Fish in the Yolo Bypass showed different patterns of methylmercury accumulation in 2001, 2002, 2003, and 2005. Methylmercury accumulated linearly with time in years when Cache Creek provided the primary source of flood flow but followed a quadratic pattern in years when flood flow was dominated by the Sacramento River.

Henneberry, Y. K., T.E.C. Kraus, J.A. Fleck, D.P. Krabbenhoft, P.M. Bachand, and W.R. Horwath (2011). "Removal of inorganic mercury and methylmercury from surface waters following coagulation of dissolved organic matter and metla-based salts." Scienct of the Total Environment 409: 7.

The presence of inorganic mercury (IHg) and methylmercury (MeHg) in surface waters is a health concern
worldwide. This study assessed the removal potential use of metal-based coagulants as a means to remove
both dissolved IHg and MeHg from natural waters and provides information regarding the importance of Hg
associations with the dissolved organic matter (DOM) fraction and metal hydroxides. Previous research
indicated coagulants were not effective at removing Hg from solution; however these studies used high
concentrations of Hg and did not reflect naturally occurring concentrations of Hg. In this study, water
collected from an agricultural drain in the Sacramento–San Joaquin Delta was filtered to isolate the dissolved
organic matter (DOM) fraction. The DOM was then treated with a range of coagulant doses to determine the
efficacy of removing all forms of Hg from solution. Three industrial-grade

coagulants were tested: ferric
chloride, ferric sulfate, and polyaluminum chloride. Coagulation removed up to 85% of DOM from solution. In
the absence of DOM, all three coagulants released IHg into solution, however in the presence of DOM the
coagulants removed up to 97% of IHg and 80% of MeHg. Results suggest that the removal of Hg is mediated by
DOM-coagulant interactions. There was a preferential association of IHg with the more aromatic, higher
molecular weight fraction of DOM but no such relationship was found for MeHg. This study offers new
fundamental insights regarding large-scale removal of Hg at environmentally relevant regarding large-scale
removal of Hg at environmentally relevant concentrations.

Henneberry, Y. K., T.E.C. Kraus, P.S. Nico, W.R. Horwath (2012). "Structural stability of coprecipitated natural organic matter and ferric iron under reducing conditions." Organic Geochemistry 48: 9.
The objective was to assess the interaction of Fe coprecipitated with dissolved organic matter (DOM) and
its effect on Fe (hydr)oxide crystallinity and DOM retention under abiotic reducing conditions. A Febased
coagulant was reacted with DOM from an agricultural drain and the resulting precipitate (floc)
was exposed to S(-II) and Fe(II). Solution concentrations of Fe(II/III) and DOM were monitored, floc crystallinity
was determined using X-ray diffraction, and the composition and distribution of functional
groups were assessed using scanning transmission X-ray microscopy (STXM) and near edge X-ray
absorption fine structure (NEXAFS) spectroscopy. Results indicate coprecipitation of Fe(III) with DOM
forms a non-crystalline floc that withstands crystallization regardless of change in pH, Fe:DOM ratio
and type of reductant added. There was no evidence that exposure to reducing conditions led to release
of DOM from the floc, indicating that coprecipitation with complex natural DOM in aquatic environments
may stabilize Fe (hydr)oxides against crystallization upon reaction with reduced species and lead
to long term sequestration of the DOM. STXM analysis identified spatially distinct regions with remarkable
functional group purity, contrary to the model of DOM as a relatively uniform complex polymer
lacking identifiable organic compounds. Polysaccharide-like OM was strongly and directly correlated
with the presence of Fe but showed different Fe binding strength depending on the presence of carboxylic
acid functional groups, whereas amide and aromatic functional groups were inversely correlated
with Fe content.

Henneberry, Y. K. C. (2012). What the Floc: Investigating the interaction of dissolved organic matter with metals in water and the subsequent effects on soil and water quality in a wetland environment. Davis, CA, University of California, Davis. PhD.

Hennessy, A. (2009). Zooplankton Monitoring 2008. iEP Newsletter. 22: 7.

Hennessy, A. (2010). Zooplankton Monitoring 2009. IEP Newsletter. 23: 8.

Hensley, G. H., and F.M. Nahhas (1975). "Parasites of fishes from the Sacramento-San Joaquin Delta, California." California Fish and Game 61: 201-208.

Henson, S. S., D. S. Ahearn, et al. (2007). "Water quality response to a pulsed-flow event on the Mokelumne river, California." River Research and Applications 23(2): 185-200.
Controlled water releases from reservoirs (i.e. artificial floods) are used as a management technique to remove fine sediments and detrital materials from spawning gravels, mobilize gravel bars and clear encroaching brush from stream banks. The effects of a managed release event on water quality were investigated on the lower Mokelumne River in the western Sierra Nevada, California. The managed release was characterized by an increase in flow over a 4-day period (from 11 to 57 m super(3) s super(-1)). Automatic pump samplers were used to collect samples for water quality from 0.7, 16.4, 37.4 and 54.4 km below Camanche Dam. These sampling sites provided water quality data for three distinct stream reaches: a gravel and sand-textured substrate reach (0.7-16.4 km), a reach characterized by lentic conditions associated with a small reservoir (16.4-37.4 km), and fine sand and silt-textured substrate reach (37.4-54.4 km). Water samples were analysed for total suspended solids (TSS), total nitrogen, ammonium (NH sub(4)-N), nitrate (NO sub(3)-N), total phosphorus, soluble reactive phosphorus (SRP), dissolved organic carbon (DOC), foecal coliforms and E. coli. Chemographs for all constituents exhibited spikes in concentration with each increase in streamflow for the rising limb. Fluxes of TSS, total P and total N released from the 0.7 to 16.4 km reach were 322, 0.32 and 0.70 Mg, respectively. The small reservoir acted as a sink for particulate materials retaining about 50% of TSS, 48% of total P and 43% of total N. However, the reservoir acted as a source of dissolved nutrients (NO sub(3)-N = 0.28 Mg and SRP = 0.055 Mg). The stream reach below the reservoir (37.4 to 54.4 km) was a source of particulate materials, dissolved nutrients and bacteria, possibly due to agricultural and urban inputs.

Herbold, B., and P.B. Moyle (1986). "Introduced species and vacant niches." The American Naturalist 128: 751-760.
The idea of “variant niches” has undergone a small resurgence recently (e.g., Lawton 1984; Price 1984). Walker and Valentine (1984) developed a model for estimating the number of unoccupied niches in ecosystems and predicted, for example, 150,000 empty niches in the “marine biosphere.” The application of their model to the real world depends on the assumption that vacant niches do exist. As the sole support for this assumption, they cited a review by Simberloff (1981) on the effects of introduced species. Simberloff (1981, p. 66, and in Walker and Valentine 1984) concluded, “The most striking result is that in so many instances (678 of 954), an introduced species has no effect whatever on species in the resident community, or on the structure and function of the community. Perhaps the second most striking result is the scarcity of extinctions apparently attendant on introductions.” Our purpose is to demonstrate that introduced species have not provided unequivocal evidence for the existence of vacant niches because the conclusions of Simberloff (1981) resulted from his special definitions of effect and from his methods of analyzing the available information. We review the reasons for rejecting the concept of vacant niches, concluding with an analysis of the effects of introduced species of fish on the aquatic communities of California.

Herbold, B., A.D. Jassby, and P.B. Moyle (1989). "The ecology of the Sacramento-San Joaquin Delta: a community profile." U.S. Fish and Wildlife Service Biological Report 85: 1-106.
This report describes an ecosystem significantly different from other delta ecosystems in North America. The Sacramento-San Joaquin Delta is one of the 60 largest river deltas in the world and is the largest river delta on the west coast. As the hub of California's water system, the delta is of immense municipal, agricultural, and industrial importance. The amount of freshwater that flows through the delta controls the delta's productivity and regulates the life cycles of many of its organisms. The vast estuary of the Sacramento and San Joaquin Rivers is one of the most highly modified and intensively managed estuaries in the world. Biological processes in the delta are obscured by the temporal dynamics of the system. Many of the most significant alterations, such as leveeing, diking, and agricultural practices, are not now recognized as such by most citizens, making conservation and protection of the delta difficult.

Herbold, B., A. D. Jassby, et al. (1992). Status and trends report on aquatic resources in the San Francisco estuary. Oakland CA, San Francisco Estuary Project, U.S. Environmental Protection Agency.

Hernes, P. J., B. Pellerin, P. Bachand, R. Spencer, R. Dyda, S. Matiasek, and B.A. Bergamaschi (2010). Agricultural impacts on stream DOC in a Sacramento River Valley watershed. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Interest in dissolved organic carbon (DOC) cycling in California waterbodies has increased due to drinking water quality concerns (formation of carcinogenic halogenated organic compounds during disinfection), the role of DOC in foodwebs, and as the potential for DOC fluxes and compositions as a diagnostic tool for land use and climate change. During a three-year period from 2006-2008, we undertook an intense study of DOC sources, processing, and fates within the Willow Slough watershed, a typical agricultural watershed in the Sacramento River Valley located in Yolo County near Davis and Woodland. Our objectives were to determine seasonality of DOC fluxes, compositions, and reactivity as well as the impact of various agricultural practices on fluxes and compositions. DOC dynamics in Willow Slough were dominated by three distinct hydrologic regimes, winter baseflow influenced largely by groundwater, spring storms influenced by flushing and overland flow, and summer irrigation influenced by different sources of water as well as irrigation practices. While winter and spring DOC concentrations and compositions were typical for an undisturbed watershed, it was clear that agricultural practices during summer had significant impacts, increasing DOC concentrations by a factor of 2-3 over what might be expected for a natural system (8 mg/L vs. 2-3 mg/L vs. the proposed EPA action level of 3 mg/L). Although there are likely several sources for increased DOC, it appears that flood irrigation practices are a primary source, while desorption from sediments may also contribute to the increase. Compositions of certain constituents (lignin phenols) are strongly correlated with total suspended sediments, an indication of potential controls on DOC by sediment management practices. Vascular plant carbon sources (as indicated by lignin biomarkers) increased during summer, while disinfection byproduct (DBP) potential decreased, in contrast to expected trends since aromatic compounds like lignin are typically assumed to be the primary source of DBP’s. However, this disconnect was also observed in biodegradation experiments in which DBP formation potential was not correlated with lignin concentrations. Optical measurements were also investigated as diagnostic tools for DOC composition, with mixed results for DBP and lignin compositions.

Herr, J., S. Sheeder, and K. van Werkhoven (2010). Application of WARMF Watershed Model to determine sources of salt and organic carbon entering the Delta from the Sacramento River. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The concentrations of salt and organic carbon are a concern for drinking water utilities with intakes in the Sacramento-San Joaquin River Delta. Under a grant obtained by the California Urban Water Agencies, an application of WARMF was created for the Sacramento River to determine the sources of the drinking water contaminants in the watershed. Meteorology, air quality, reservoir release, diversion, and point source data provided inputs for the model’s daily time step. Water and its chemical components were tracked through inflows, diversions, precipitation, irrigation, canopy, shallow groundwater, and surface water processes. Measured flow and water quality data was used for model calibration. The model was calibrated for flow, temperature, suspended sediment, electrical conductivity as an analog for salinity, and organic carbon using data collected at various time periods from the 1970’s through 2007. The calibrated models were used to identify the sources of pollutants overall and by season and year. The sources were broadly divided into inflows from reservoirs above the model domain, point sources, and the individual land uses of nonpoint source loading. Inflows from upstream reservoirs contributed 53% of the salinity entering the Delta from the Sacramento River with nonpoint sources contributing 43% and 3% from point sources. Natural land covers were the largest source of nonpoint source salt loading, but rice had the greatest loading per land area. Peak concentration occurred in the summer. Nonpoint sources

contributed 48% of organic carbon loading in the Sacramento River watershed. Upstream inflows were 27% of the loading, production of organic matter within surface water was 16% of loading, and point sources contributed 9%. Natural land covers were the largest component of nonpoint source organic carbon load, but rice had the greatest loading per land area. Organic carbon had two annual peak concentrations, during summer irrigation season and during winter runoff.

Herr, J., R. Smith, V. Kretsinger-Grabert, and J. Dickey (2010). Simulating salt and nitrate water quality in California's Central Valley. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Salt and nitrate management to protect surface water and groundwater quality is a key issue facing both state regulators and water users in the Central Valley. CV-SALTS, a stakeholder initiative, is addressing this issue by facilitating the development of such plans throughout the Central Valley. The Central Valley Salinity Coalition, the funding body of CV-SALTS, sponsored the Salt and Nitrate Source Pilot Implementation Study to develop an accounting methodology and apply it to three pilot study areas, including the Yolo County, Modesto, and Tule River areas. Each area was divided into surface water, land catchments with many land cover classes, near-surface groundwater, and deeper groundwater. Using a multi-disciplinary approach, salt and nitrate were tracked as they were transported and transformed into, within, and out of all catchments in the respective areas. Important processes in the mass-balances included fertilizer and other land application, groundwater pumping for irrigation and municipal use, diversion, irrigation, chemical reactions, surface water inflows, point sources, and flow from near-surface groundwater to surface water and to deeper groundwater (recharge). The Watershed Analysis Risk Management Framework (WARMF) model was used to track salt and nitrate through surface water and near-surface groundwater. Recharge and pumpage results for three groundwater models (e.g., Central Valley Hydrologic Model (CVHM) for the Yolo area and locally applied MODFLOW models for the Modesto and Tule River areas) were provided as inputs to the WARMF model. Detailed land cover processing, particularly for agricultural lands and dairy facilities, was used to define model inputs related to land cover classes. The products of the analyses were closed mass balances that fully accounted for salt and nitrate sources and sinks resulting from different land cover classes, water sources, and hydrologic conditions. The successfully applied methodology provides a template for future mass balance analyses elsewhere in the Central Valley.

Herren, J. R., and S.S. Kawasaki (2001). Inventory of water diversions in four geographic areas in California's Central Valley. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 343-355.

Water diversions in California, used primarily for agricultural, municipal, and industrial applications, have been considered a possible culprit in the decline of many California fishes. In 1991, the California Department of Fish and Game (DFG) initiated a study using the Global Positioning System (GPS) to inventory water diversions. The initial focus was on the Sacramento-San Joaquin Delta (Delta) and the Suisun Marsh, then continued to the Sacramento River and the San Joaquin River Basin. The inventory was to find, quantify, describe, and categorize diversions along waterways where California fish may be affected by water diversions. As of April 1997, 3,356 diversions have been located and mapped in a Geographical Information System (GIS). Approximately 98.5% of the diversions identified were either unscreened or screened insufficiently to prevent fish entrainment. The GPS data were post processed to provide a horizontal accuracy of ±5 meters. The information was primarily collected by visual inspection of diversions on the stream bank. Information is maintained in a Microsoft Access database.

Hershler, R. (1995). "New freshwater snails of the genus Pyrgulopsis (Rissooidea: Hydrobiidae) from California." Veliger 38(4): 343-373.

Hess, K. W. (2002). "Spatial interpolation of tidal data in irregularly-shaped coastal regions by numerical solution of Laplace's equation." Estuarine, Coastal and Shelf Science 54(2): 175-192.

A method was developed for spatially interpolating tidal constituent amplitude and phase data using the numerical solution of Laplace's equation. The solution matches the input data values at ' internal boundaries ', i.e., locations that represent observation stations. The boundary condition at land-water interfaces assumes that the normal derivative is proportional to the spatially-averaged value of the derivative in the normal direction. By adjusting the constant of proportionality at land boundaries, realistic distributions were obtained. An equivalent solution field can also be reconstructed by generating a set of weighting functions, thereby minimizing the number of solution fields needed. The method was tested in a simple basin and the solution was evaluated for a variety of parameters such as cell size, grid orientation, and boundary proportionality constant. The method was then applied to San Francisco Bay and distributions of tidal constituent amplitudes and epochs were compared with those generated by a numerical circulation model. Copyright 2002 Elsevier Science Ltd

Hester, M., and J. Willis (2010). Constraints on the expansion of Schoenoplectus californicus (tule) in the Liberty Island wetland system. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The appropriate management of the upper Delta wetlands is contingent on, among other things, an effective understanding of the establishment and colonization dynamics of local vegetation. We recently initiated a field transect study investigating environmental factors associated with marsh vegetation colonization dynamics, as a portion of a larger, interdisciplinary project in the Upper Delta (BREACH III). Plots were established along transects in the following habitats: interior marsh, marsh edge, mudflat edge, and mudflat in both protected and unprotected areas of the east and west sides of Liberty Island. Tule stem height and density, as well as soil redox potential and elevation were quantified in plots. Soil cores were also collected in all plots for determination of relevant edaphic variables. Preliminary data analysis thus far suggests that lower soil bulk densities and higher plot elevations are correlated with greater tule stem densities and heights in the interior marshes. Also, surface soil redox potential appears to decrease with decreased tule stem density and lower elevation, likely as a function of reduced plant root oxygenation and greater flooding intensity. Analysis of soil samples for nutrient and organic matter content are currently underway. From our preliminary findings, we suggest that the further expansion of current marsh in Liberty Island will proceed slowly, requiring that the adjacent vegetation ameliorate high soil bulk densities through vegetative tillering and low elevation via trapping of sediments along clonally expanding vegetative edges. Vegetative and soil characteristics will continue to be monitored on a semi-annual basis to further refine these findings. We anticipate setting up a manipulative vegetation transplant study this summer to elucidate competitive processes among tules and cattail species to further enhance our understanding of marsh colonization dynamics in this valuable region.

Hestir, E. L., S. Khanna, M.J. Santos, and S.L. Ustin (2010). Monitoring and mapping plant ecophysiology and vegetation succession in a flooded island using airborne imaging spectroscopy. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Monitoring vegetation succession and plant community health over large spatial scales is effectively accomplished with remote sensing. Imaging spectroscopy provides both spatial information as well as high-resolution continuous spectroscopic information from visible to shortwave reflected spectrum. This powerful technology provides the data needed to map vegetation communities, plant functional types, and even species. When specific absorption features are analyzed, information about the concentration of plant pigments and water can be quantified.. We used airborne imaging spectroscopy (the HyMap sensor) collected during June-July 2004-2008 to map wetland vegetation community changes and plant health in Liberty Island.. The results of our study show emergent vegetation expansion into open water areas from 2004 to 2008. Most expansion occurred in the north island, in the “steps.” Plant pigment and water content varied between years, indicating differing levels of stress. This flooded island can be considered a natural experiment under which to examine the successional trajectory of wetland vegetation after a levee breach. Spectroscopic imaging allows inferences about plant ecophysiology and vegetation succession dynamics; the kind of information that is critical to understanding the evolution and ecological trajectory of flooded islands in the Sacramento-San Joaquin Delta.

Hestir, E. L., M.J. Santos, E. Duncan, J.K. Conrad, R. Hestir, A. Sih, and S.L. Ustin (2010). Monthly patterns of submerged species composition and biomass in the Sacramento San Joaquin River Delta. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Submerged aquatic plant (SAP) communities in deltaic environments are highly dynamic, especially when the community is impacted by the presence of Invasive Alien Species (IAS). Since 2004 we monitored annual trends in early summer in the distribution of SAP communities and their potential effects on aquatic habitat in the Sacramento-San Joaquin Delta using airborne hyperspectral remote sensing. These efforts assessed interannual variability, but seasonal variability within years was not determined. Understanding within-year variability in SAP communities can clarify interactions between these plant communities and the abiotic delta environment, and inform decisions on the timing of management actions towards the control of key IAS. To address these issues, we undertook intensive monthly sampling of the SAP communities from December 2008 to November 2009 at 33 stratified randomly selected sites that encompassed the natural variability of the Delta ecosystems. At each site, 10-45 SAP samples were collected by raking, and each of the SAP species was separated and weighed individually in the lab. We found a significant increase in species richness over the year, mostly due to an increase in native species richness. Nonetheless, this pattern does not hold for biomass, where the IAS Egeria densa biomass is about 20 times higher than any other SAP and accounts for 85% of the monthly biomass. The phenology of most species show a clear increase in biomass in the summer and early fall, with a decrease over the winter and spring; however, non-native biomass peaks earlier in the year (April) whereas native biomass peaks between July and August. These results show that the biomass and composition of submerged aquatic plant communities are highly variable within the year and that the different phenological timing between natives and non-natives may explain the IAS dominance in this system.

Hestir, E. L., D.H. Schoellhamer, T. Morgan-King, and S.L. Ustin (2010). An observed step change in Delta turbidity following 1982-1983 El Nino floods. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Sediment transport influences the geomorphology, biogeochemical cycling, pollutant load, and ecology of river deltas and estuaries. In the Sacramento-San Joaquin Delta, turbidity is largely considered a surrogate of suspended sediment concentration, and has been declining over the past 30 years. This has contributed to dramatic changes in the ecology of the Delta and to the decline of the endemic and endangered delta smelt. The declining turbidity trend in the Delta has been attributed to reduced sediment inputs and expansion of invasive submerged aquatic vegetation. In this study, we analyzed historic monthly turbidity records collected by the California Department of Water Resources Environmental Monitoring Program from 1975-2008. We investigated structural changes in the turbidity trend, and identified a significant step decrease in turbidity after the beginning of the 1984 water year at nine different sites within the Delta. This significant decrease in Delta turbidity appears to have been caused by the combination of large El-Nino driven winter floods from both the San Joaquin and Sacramento Rivers in 1982-1983 and the high inflows throughout the summer. We suggest that these extended high flow events flushed the erodible sediment pool from the Delta into the San Francisco Bay. This event has left the Delta in its current, low-turbidity state. Another study found that a step decrease in suspended sediment concentration in San Francisco Bay in 1999 may have been caused by depletion of erodible sediment. This indicates that depletion of erodible sediment may have progressed downstream and, if the erodible sediment pools were created by hydraulic mining in the late 1800s, sedimentation in the estuary has largely recovered from hydraulic mining.

Hestir, E. L., D.H. Schoellhamer, T. Morgan-King, J. Greenberg, and S.L. Ustin (2010). Turbidity declines and submerged aquatic vegetation expansion in the

Sacramento - San Joaquin Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
We investigated interactions between submerged aquatic vegetation (SAV) and turbidity in the Sacramento-San Joaquin Delta, California. Feedback dynamics were examined using in situ turbidity and velocity meters and SAV maps derived from airborne imaging spectroscopy. We then analyzed historical turbidity data from the Delta, which showed a decline in turbidity coinciding with an expansion of SAV. Turbidity significantly declined from 1975-2008 (-1.3% /year), and the decline was highly correlated with SAV cover (R2=0.9, p=0.003). To determine if SAV contributed to the increased water clarity, we used quantile regression to model the limitations of SAV cover on high turbidity. We found that annual maximum velocities exceeding 0.49 ms-1 constrain SAV distribution, and that SAV cover has a negative linear relation with turbidity, and limits high turbidities at 13.8-15.8 NTU. We hypothesize that diminishment of the hydraulic mining sediment pulse, armoring of the Sacramento River channel, and sediment trapping in reservoirs and flood bypasses has reduced sediment supply and favored SAV expansion. Turbidity declines after 1975 were promoted by the expanding SAV cover in the Delta. We estimate that the expansion of SAV cover after 1975 provides a relative contribution of 21-70% of the total declining trend in turbidity. Furthermore, the relations between velocity, SAV, and turbidity indicate potential feedbacks, suggesting the possibility of an irreversible shift in the ecosystem state from a low SAV-high turbidity ecosystem to a high SAV-low turbidity ecosystem. Lower turbidity conditions have negatively impacted delta smelt habitat, however, removal of the vegetation may not lead to increases in turbidity that restore habitat due to the loss of sediment supply.

Hestir, E. L., S. Khanna, et al. (2008). "Identification of invasive vegetation using hyperspectral remote sensing in the California Delta ecosystem " Remote Sensing of Environment 112(11): 4034-4047.
Estuaries are among the most invaded ecosystems on the planet. Such invasions have led in part, to the formation of a massive $1 billion restoration effort in California's Sacramento–San Joaquin River Delta. However, invasions of weeds into riparian, floodplain, and aquatic habitats threaten the success of restoration efforts within the watershed and jeopardize economic activities. The doctrine of early detection and rapid response to invasions has been adopted by land and water resource managers, and remote sensing is the logical tool of choice for identification and detection. However meteorological, physical, and biological heterogeneity in this large system present unique challenges to successfully detecting invasive weeds. We present three hyperspectral case studies which illustrate the challenges, and potential solutions, to mapping invasive weeds in wetland systems: 1) Perennial pepperweed was mapped over one portion of the Delta using a logistic regression model to predict weed occurrence. 2) Water hyacinth and 3) submerged aquatic vegetation (SAV), primarily composed of Brazilian waterweed, were mapped over the entire Delta using a binary decision tree that incorporated spectral mixture analysis (SMA), spectral angle mapping (SAM), band indexes, and continuum removal products. Perennial pepperweed detection was moderately successful; phenological stage influenced detection rates. Water hyacinth was mapped with modest accuracies, and SAV was mapped with high accuracies. Perennial pepperweed and water hyacinth both exhibited significant spectral variation related to plant phenology. Such variation must be accounted for in order to optimally map these species, and this was done for the water hyacinth case study. Submerged aquatic vegetation was not mapped to the species level due to complex non-linear mixing problems between the water column and its constituents, which was beyond the scope of the current study. We discuss our study in the context of providing guidelines for future remote sensing studies of aquatic systems.

Heubach, W., R.J. Toth, and A.M. McCready (1963). "Food of young-of-the-year striped bass (Roccus saxatilis) in the Sacramento-San Joaquin River system." California Fish and Game 49: 224-239.

Heubach, W. (1969). "Neomysis awatschensis in the Sacramento-San Joaquin River estuary." Limnology and Oceanography 14: 533-546.

Heubach, W., R. J. Toth, et al. (1963). "Food of young-of-the-year striped bass

(Roccus saxatilis) in the Sacramento-San Joaquin River system." California Fish and Game 49: 224-239.

Hieb, K., and T. Veldhuizen (1998). Mitten crabs on the move. IEP Newsletter. 11: 3-4.

Hieb, K., T. Greiner, and S. Slater (2004). San Francisco Bay Species: 2003 Status and Trends Report. IEP Newsletter. 17: 12.

Hieb, K. (2009). 2008 Status and Trends Report Common Crabs of the San Francisco Estuary. IEP Newsletter. 22: 5.

Hieb, K. (2010). 2009 Status and Trends Report Common Crabs of the San Francisco Estuary. IEP Newsletter. 23: 5.

Hieb, K. (2010). Biological communities in the San Francisco Bay respond to ocean climate patterns. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Higgins, S. A., B. E. Jaffe, et al. (2007). "Reconstructing sediment age profiles from historical bathymetry changes in San Pablo Bay, California." Estuarine, Coastal and Shelf Science 73(1-2): 165-174.
Sediment age profiles reconstructed from a sequence of historical bathymetry changes are used to investigate the subsurface distribution of historical sediments in a subembayment of the San Francisco Estuary. Profiles are created in a grid-based GIS modeling program that stratifies historical deposition into temporal horizons. The model's reconstructions are supported by comparisons to profiles of super(1) super(3) super(7)Cs and excess super(2) super(1) super(0)Pb at 12 core sites. The predicted depth of the 1951 sediment horizon is positively correlated to the depth of the first occurrence of super(1) super(3) super(7)Cs at sites that have been depositional between recent surveys. Reconstructions at sites that have been erosional since the 1951 survey are supported by a lack of detectable super(1) super(3) super(7)Cs and excess super(2) super(1) super(0)Pb below the upper 6-16cm of the core. A new data set of predicted near-surface sediment ages was created to illustrate an application of this approach. Results demonstrate other potential applications such as guiding the spatial positioning of future core sites for contaminant measurements.

Hinshaw, S., R. Dahlgren, J. Harrison, and B. Deemer (2010). Assessment of excess N2 and groundwater N2O in the San Joaquin River. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
A joint USGS-UCD study monitoring groundwater in the riparian zone of a 59 mile reach of the San Joaquin River between the confluence of Salt Slough and Vernalis documented unexpected nitrogen dynamics. Groundwater samples were taken from 0.3 m and 2 m depths in 30 locations along the river with three cross sections at the 20, 50 and 80% width at each location. Approximately 90% of the groundwater had nitrate concentrations less than detection (<0.10 mg N/L), with a few hot spots reaching 14.4 mg N/L. In contrast, median ammonium concentrations were 0.42 mg N/L with maximum concentrations reaching 29 mg N/L. Anoxic conditions suggested denitrification was the main factor contributing to low nitrate concentrations in the groundwater. N2:Ar ratios were measured by membrane inlet mass spectrometry and were used to estimate excess dissolved N2concentrations. Excess N2 relative to Ar can be attributed to the denitrification process. Of the 158 groundwater samples measured, 74% of the samples contained excess N2 with concentrations up to 8.65 N2 mg/L. Excess N2 concentrations displayed a general increase in the downstream direction. Deeper groundwater sites had significantly higher N2 concentrations coinciding with decreased O2 and cooler temperatures. The presence of excess N2 documents the importance of denitrification in removing nitrate from the groundwater. Preliminary studies suggest that the high ammonium concentrations results from anaerobic mineralization of the river bed sediments. Further analysis will focus on evaluating the fate of nitrogen in at three specific sites and measuring coupled N2O and N2 rates from riparian soils, surface water, shallow

groundwater and benthic sediments.

Hinton, D. A. (1998). Multiple stressors in the Sacramento River watershed. Fish ecotoxicology., Birkhaeuser Verl., Basel (Switzerland), 1998. T. Braunbeck, D. E. Hinton and B. Streit. Basel; Switzerland, Birkhaeuser Verl.: 303-317.
Aquatic biota in the Sacramento River watershed are stressed by diversion of river flows, by historical mining resulting in cadmium, copper, zinc, and mercury, and, more recently, contamination by agricultural and urban chemical runoff. In addition, the proposed redirection of drainage of saline waters -containing selenium - from the western slope of the San Joaquin River into the Delta formed by the confluence of the Sacramento and San Joaquin Rivers could add to the stress on resident organisms. These combined stressors have led to deterioration in surface water quality and the aquatic habitat. The potential interaction of these stressors, coupled with invasions of foreign species and the export of juvenile fish into aqueducts, has driven several species of fish to near extinction in the system. Effects of historical contamination by heavy metals are potentially exacerbated by presence of organophosphate pesticides, at concentrations exceeding National Academy of Sciences recommendations, throughout the lower watershed and the San Francisco Bay. The Asian clam, Potamocorbula amurensis, an introduced non-indigenous species has apparently become a preferred food item of the sturgeon, Acipenser transmontanus, an important sport and aquaculture species. Since this introduction, sturgeon body burdens for selenium have increased dramatically and analytical chemistry of P. amurensis indicates that these organisms are effective bioaccumulators of selenium. This review examines potential ecotoxicity associated with multiple stressors in the watershed. Data from field monitoring, laboratory toxicity assays with ambient water, and ecotoxicologic investigations are reviewed. Potential designs for multiple stressor investigations are discussed. The information presented on this watershed illustrates the challenge to investigators seeking to evaluate multiple stressor effects on riverine and estuarine organisms.

Hladik, M., K. Smalling, and K. Kuivila (2010). Occurrence of pyrethroid insecticides in water, sediment and biota. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Pyrethroid insecticides are of increasing environmental concern because of their widespread use and high aquatic toxicity. Pyrethroids are frequently detected in California in both agricultural and urban areas and more recently pyrethroids have become a concern in other parts of the United States. Pyrethroid insecticides are highly hydrophobic compounds (log Koc >5), tend to bind tightly to sediments and have been detected in aquatic organisms. To better understand the environmental occurrence of pyrethroids, sensitive methods have been developed for the analysis of 14 pyrethroids in water, sediment (bed and suspended) and biota (fish, crab embryos and sand crabs). Data from agricultural and urban areas are summarized including nationwide studies conducted by the USGS in 2007 and 2009. Agricultural areas tend to have a greater variety of pyrethroids detected while urban areas tend to have higher concentrations. Preliminary results from much smaller studies on aquatic uptake of pyrethroids indicate that several of the more ubiquitous pyrethroids (bifenthrin, cyfluthrin, cypermethrin and permethrin) were detected in fish, sand crabs and crab embryos from agricultural and urban areas in Northern and Central California. A greater understanding of pyrethroid occurrence and fate can help in determining potential environmental effects.

Hobbs, J., R. Kurth, J. Kindopp, and B. Cavallo (2010). Proportion of hatchery-origin fish among Feather River Chinook salmon spawners, 2002-2008. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Problem Statement: In-river spawning of hatchery-origin Chinook salmon is known to compromise the genetic integrity of natural-origin populations through outbreeding depression and genetic homogenization. The abundance of natural-origin Chinook in most Central Valley tributaries is currently unknown. The recent implementation of a constant fractional marking program, where 25% of hatchery fall run Chinook are coded wire tagged (CWT) and adipose fin clipped, is expected to improve future estimates of hatchery composition. However, complexities of

accounting for tag loss, inter-basin straying, age composition, and intermingling of hatchery fish with different tagging rates (e.g. 100% marking and tagging of Feather River spring run Chinook, and Mokelumne River/Merced River Hatchery fall run Chinook) mean that precise estimates of natural-origin fall run Chinook abundance may remain elusive in the absence of alternate methods. The precise and rapid assessment of natural-origin Chinook population status is essential for resource managers evaluating habitat restoration efforts, managing hatcheries, operating water projects, and planning harvest regulations. Approach: To help address these resource management challenges for Feather River fall and spring run Chinook, we analyzed microstructure and microchemistry of otoliths collected during seven years of salmon carcass surveys . Specifically, we analyzed calcium architecture and the Sr isotope ratios (87Sr/86Sr) determine the proportion of hatchery and wild origin fish spawning, and the spatial distribution of hatchery and wild origin fish spawning in the river. Results: Our results show that a significant proportion of in-river spawning Chinook salmon are hatchery-origin fish. High rates of in-river spawning hatchery-origin Chinook documented in our study indicate that fitness of natural origin Chinook may be significantly impaired and suggest that introgression between hatchery and natural origin Chinook may be a factor contributing to the depressed status Central Valley Chinook salmon. Conclusions: This study supplies managers critical information regarding the influence of hatchery Chinook salmon on the Central Valley spring and fall run Chinook population, and highlights the urgent need for better management and monitoring of salmonid hatcheries.

Hobbs, J., R. Kurth, J. Kindopp, and B. Cavallo (2010). Reconstructing inter-annual variability of delta smelt life history with otoliths. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Problem Statement: The delta smelt population has experienced dramatic declines in the past and has continued to precipitously drop in recent years. The cause(s) of the decline have yet to be determined, and is likely the result of multiple impacts on the population (e.g. food limitation, contaminants, freshwater exports from the estuary), which can operate spatially. Approach: To look back on the processes that result in poor recruitment, we are investigating the spatial extant of the population structure through otolith geochemistry for juvenile and adults collected during monitoring surveys, including the relative impact that the freshwater exports may have on the delta smelt population structure. In addition we are investigation growth rate variability of successful recruits to test the hypothesis that reduced zooplankton prey abundance has resulted in reduced growth rates. Results: In this study we investigated the spatial and temporal variability of birthdate, natal origin and growth of delta smelt recruits from 1999-2008 and for exported larvae in 2000,2001, 2008 and 2009. Overall, a majority of fish originated from Sacramento River water, while a small proportion originated in San Joaquin River water and the low-salinity zone. Juvenile rearing habitats varied with X2, with most of the successful recruits using the freshwater delta when X2 was at the confluence. Fishes residing in San Joaquin River water during the juvenile stage showed relatively poor growth and recruitment from summer to fall. During wet years (e.g. 2000), the exports preferentially effect early born San Joaquin River cohorts, while in dry years (e.g. 2001) the exports have a larger relative impact on the entire population by entraining water and smelt from the Sacramento River. Conclusion: This study provides important information regarding the spatial variability associated with recruitment and infers a potential problem with fishes residing in San Joaquin River water. In addition we show that exports can have qualitative impacts on the population structure, which may result in impacts beyond absolute entrainment loss.

Hobbs, J., L. Lewis, et al. (2010). "The use of otolith strontium isotopes (87Sr/86Sr) to identify nursery habitat for a threatened estuarine fish." Environmental Biology of Fishes 89(3): 557-569.

Nursery habitats are larval or juvenile habitats that disproportionately contribute individuals to adult populations of a species. Identifying and protecting such habitats is important to species conservation, yet evaluating the relative contributions of different larval habitats to adult fish populations has proven difficult at best. Otolith geochemistry is one available tool for reconstructing

previous habitat use of adult fishes during the early life history, thus facilitating the identification of nursery habitats. In this study, we compared traditional catch surveys of larval-stage longfin smelt (Spirinchus thaleichthys) occurring in habitats of different salinities to corresponding larval-stage salinity distributions of sub-adult/adult longfin smelt estimated using otolith geochemical techniques. This allowed us to evaluate the relative contribution of larvae from waters of various salinities to sub-adult/adult populations of longfin smelt. We used laser ablation MC-ICP-MS on otoliths and an empirically-derived relationship between strontium isotope ratios (87Sr/86Sr) of waters across the estuarine salinity gradient to reconstruct the larval salinity history of longfin smelt. Salinity values from the larval region of sub-adult/adult otoliths (corresponding to standard lengths of ca.10-mm) were compared to corresponding catch distribution of larval longfin smelt (≤ 10-mm) from 4 year-classes (1999, 2000, 2003 and 2006) in the San Francisco Estuary spanning a period when the population underwent a dramatic decline. Though the catch distribution of larval-stage longfin smelt was centered around 4-ppt and did not vary significantly among years, salinity distributions of sub-adult/adult were lower and narrower (ca. 2-ppt), suggesting that low-salinity habitats disproportionally contributed more recruits relative to both freshwater and brackish water habitats and, therefore, may function as important nursery areas. Furthermore, the relative importance of the low salinity zone (ca. 2-ppt) to successful recruitment appeared greatest in years following the longfin smelt population decline. Our results indicate that otolith strontium isotopes (87Sr/86Sr) are a powerful tool for identifying nursery habitats for estuarine fishes.

Hobbs, J. A., P. Crain, and P.B. Moyle (2010). Monitoring the response of fish assemblages to restoration in the South Bay Salt Ponds. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Problem Statement: Greater than 90% of wetland habitats in SF Bay have been lost due to land reclamation for agricultural and urban development. In South Bay, the largest wetland restoration effort in the U.S. was established to restore a diversity of habitats in historic salt ponds. The effects of this restoration on fish fauna is a priority goal of the South Bay Salt Pond Restoration Program and it’s effects are currently unknown. Approach: In this study we are developing a flexible, comprehensive monitoring program to evaluate the effects of restoration on the fish species assemblages and sentinel species health in salt pond habitats located in the Alviso complex in South San Francisco Bay, California. We employed several commonly used and new fish sampling techniques in restored pond habitats and adjacent marsh and slough habitats to monitor salt pond habitats of different restoration age to assess the temporal trajectory of pond restoration effects on fish assemblages. We also conduct detailed investigations into the health of the sentinel species Gillichthys mirabilis, measuring indicators of health such as growth, reproductive output, feeding condition, and survival in pond A8. Our interdisciplinary approach to assessing fish health will provide novel diagnostic evidence of the potential impacts of re-introducing legacy contaminants into the environment from restoration activities. This study will develope a comprehensive, state of the art monitoring program for the Salt Pond Restoration Program. Relevance: This study provides vital information to the Delta Authority on the effects of intertidal wetland restoration on fish fauna in SF Bay, and could be used to guide future restoration efforts and facilitate the effective implementation of the Bay Delta Conservation Plan.

Hobbs, J. A., G.Castillo, J. Lindberg, and G. Tigan (2010). Testing the efficacy of rrans-generational marking of an endangered fish with strontium chloride hexahydrate & near-real time monitoring of SWP delta smelt salvage for hatchery origin and cohort structure. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Hobbs, J. A., W. A. Bennett, et al. (2007). "Classification of larval and adult delta smelt to nursery areas by use of trace elemental fingerprinting." Transactions of the American Fisheries Society 136(2): 518-527.

Different environmental conditions among habitats may generate unique elemental patterns within fish otoliths that can be used to trace the life history as well as the potential natal origin of migratory species. We investigated the use of trace elements in otoliths as natural tags for determining the natal origins of larval and adult delta smelt Hypomesus transpacificus within a single estuary. Larval fish were collected at potential natal sites within the San Francisco Bay Estuary-the North, Central, South, and West Delta areas, Suisun Bay, and Napa River-during May-June 1999; adults were collected in November 1999 throughout Suisun Bay. Using laser ablation inductively coupled plasma mass spectrometry, we assayed trace elements from core (natal) regions of the otolith (Sr:Ca, Mg:Ca, and Ba:Ca ratios). Linear discriminant function analysis (LDFA) was 90.9-100% successful at classifying larval fish to their natal habitats (Napa River, Sacramento River, and Delta). Adults of unknown natal origin were assigned to their natal regions using the larval fingerprints from LDFA and a maximum likelihood mixed-stock approach. For the 1999 year-class, we determined that a majority of the population originated from the Delta (77-79%) and a small but significant proportion of the population originated from the Napa River (16-18%) and Suisun Bay (4-8%). These data highlight the value of trace elements as natural tags for determining the natal origins of young fish and the relative contribution of different habitats to the adult population within a single estuary.

Hobbs, J. A., W. A. Bennett, et al. (2006). "Assessing nursery habitat quality for native smelts (Osmeridae) in the low-salinity zone of the San Francisco estuary." Journal of Fish Biology 609: 907-922.

Habitat quality was assessed for two native osmerids, delta smelt Hypomesus transpacificus and longfin smelt Spirinchus thaleichthys, between two distinct nursery areas located in the lowsalinity zone of the San Francisco estuary. The relationship between several variables was investigated including fish density, fish size, feeding success and the general condition of larvae as well as juveniles for both species. The nursery habitats that were evaluated included the North and South Channels of Suisun Bay. The results showed higher densities of zooplankton and decreased water velocities for the North Channel when compared to the South Channel. The dominant prey item was calanoid copepod Pseudodiaptomus forbesi for both species although longfin smelt residing in the North Channel also included another copepod in their diets, Acanthocyclops spp. In both locations, delta smelt fed predominantly during daytime flood tides, while longfin smelt feeding appeared to continue into the night hours. When both locations were compared, delta smelt in the North Channel exhibited higher densities, larger sizes, increased somatic condition and larvae <15 mm standard length demonstrated greater feeding success. Longfin smelt, exhibited similar densities, feeding success and size distributions between both channels, but generally showed poorer somatic condition for the South Channel, potentially due to energetic costs associated with documented vertical migration behaviour. Overall, the physical conditions of the North Channel provided superior habitat for both species, while the South Channel afforded only marginal habitat for longfin smelt and very poor habitat for delta smelt. Therefore, the North Channel of Suisun Bay acts as critical nursery habitat by providing better feeding and growing conditions leading to increased health and survival for both species.

Hobbs, J. A., W. A. Bennett, et al. (2007). "Modification of the biological intercept model to account for ontogenetic effects in laboratory-reared delta smelt (Hypomesus transpacificus)." Fishery Bulletin 105(1): 30-38.

We investigated age, growth, and ontogenetic effects on the proportionality of otolith size to fish size in laboratory-reared delta smelt (Hypomesus transpacificus) from the San Francisco Bay estuary. Delta smelt larvae were reared from hatching in laboratory mesocosms for 100 days. Otolith increments from known-age fish were enumerated to validate that growth increments were deposited daily and to validate the age of fish at first ring formation. Delta smelt were found to lay down daily ring increments; however, the first increment did not form until six days after hatching. The relationship between otolith size and fish size was not biased by age or growth-rate effects but did exhibit an interruption in linear growth owing to an ontoge netic shift at the postflexon stage. To back-calculate the size-at-age of indi vidual fish, we modified the biological intercept (BI) model to account for ontogenetic changes in the otolith-size-fish-size relationship and com pared the results to the time-varying growth model, as well as the modified Fry model. We found the modified BI model

estimated more accurately the size-at-age from hatching to 100 days after hatching. Before back-calculat ing size-at-age with existing models, we recommend a critical evaluation of the effects that age, growth, and ontogeny can have on the otolith-size-fish-size relationship.

Hobbs, J. A., Q. Z. Yin, et al. (2005). "Retrospective determination of natal habitats for an estuarine fish with otolith strontium isotope ratios." Marine and Freshwater Research 56(5): 655-660.

We investigated the ability of strontium isotope ratios (Sr-87/Sr-86) in otolith cores to record the natal habitats of juvenile delta smelt Hypomesus transpacificus from the San Francisco Estuary, USA. Young delta smelt (< 60 days old) were collected during the California Department of Fish and Game 20-mm Survey in May and June of 1999 at several potential natal areas: Napa River, Suisun Marsh, West Delta, North Delta, Central Delta, South Delta and East Delta. The core region of sagittal otoliths was assayed with laser ablation-multicollector inductively coupled plasma mass spectroscopy. The laser ablation technique provided precise estimates of Sr-87 : Sr-86 ratios with relative standard deviation of 0.003% (one sigma). Isotope ratios ranged from 0.7065 to 0.708 and were different among natal habitats. However, natal habitats within the delta region were not discernable among each other, and reflect the mixing of the two major rivers, Sacramento River and San Joaquin River within the delta. We will therefore be able to determine natal habitats for delta smelt by assaying the core region of the otoliths. The application of strontium isotope ratios (Sr-87/Sr-86) in fish otoliths will greatly improve conservation efforts for this protected species.

Hoenicke, R., J. A. Davis, et al. (2003). "Effective application of monitoring information: The case of San Francisco Bay." Environmental Monitoring and Assessment 81: 15-25.

The San Francisco Estuary Regional Monitoring Program (RMP) for Trace Substances is an innovative partnership among a regulatory agency, more than 70 regulated entities, and an independent scientific organization. The institutional arrangement behind the RMP has made the regulatory system increasingly responsive to emerging management needs, particularly with regard to the development of total maximum daily loads and ecosystem impairment assessment. Through multiagency partnerships within and outside the RMP institutional structure, major information gaps for several pollutants of concern have been narrowed, resulting in a successful consensus-based regulatory approach to managing copper and nickel mass inputs into the Estuary. Short-term research efforts, based upon monitoring results, helped identify the most cost-effective control and remediation options for various bioaccumulative substances. Additionally, adaptive changes to the monitoring program documented the existence of widespread aquatic toxicity in the Estuary that is apparently due to pesticide runoff from agricultural and urban areas. One of the most important contributions of this collaborative monitoring program is the deliberate and systematic adjustment of management and research questions that serve to influence and add relevance to the overall research agenda related to San Francisco Estuary ecosystem assessment.

Hoenicke, R., D. R. Oros, et al. (2007). "Adapting an ambient monitoring program to the challenge of managing emerging pollutants in the San Francisco Estuary." Environmental Research 105(1): 132-144.

While over seven million organic and inorganic compounds that have been indexed by the American Chemical Society's Chemical Abstracts Service in their CAS Registry are commercially available, most pollution monitoring programs focus only on those chemical stressors for which regulatory benchmarks exist, and have been traditionally considered responsible for the most significant human and environmental health risks. Until the late 1990s, the San Francisco Estuary Regional Monitoring Program was no exception in that regard. After a thorough external review, the monitoring program responded to the need for developing a pro-active surveillance approach for emerging pollutants in recognition of the fact that the potential for the growing list of widely used chemical compounds to alter the integrity of water is high. We describe (1) the scientific and analytical bases underlying a new surveillance monitoring approach; (2) summarize approaches used and results obtained from a forensic retrospective; (3) present the growing data set on

emerging pollutants from surveillance monitoring and related efforts in the San Francisco Bay Area to characterize newly targeted compounds in wastewater streams, sediment, storm water runoff, and biota; and (4) suggest next steps in monitoring program development and applied research that could move beyond traditional approaches of pollutant characterization. Based on the forensic analysis of archived chromatograms and chemical and toxicological properties of candidate compounds, we quantified a variety of synthetic organic compounds which had previously not been targeted for analysis. Flame retardant compounds, pesticides and insecticide synergists, insect repellents, pharmaceuticals, personal care product ingredients, plasticizers, non-ionic surfactants, and other manufacturing ingredients were detected in water, sediment, and/or biological tissue samples. Several of these compounds, especially polybrominated diphenyl ether flame retardants, exhibited concentrations of environmental concern. We also describe environmental management challenges associated with emerging pollutants and how pro-active surveillance monitoring might assist in implementing a more holistic approach to pollution prevention and control before emerging pollutants become a burden on future generations.

Hoffman, D. J., H. M. Ohlendorf, et al. (1998). "Association of mercury and selenium with altered glutathione metabolism and oxidative stress in diving ducks from the San Francisco Bay region, USA." Environmental Toxicology and Chemistry 17(2): 167-172.

Adult male greater scaup (Aythya marila), surf scoters (Melanitta perspicillata), and ruddy ducks (Oxyura jamaicensis) were collected from Suisun Bay and coastal Tomales Bay in the greater San Francisco Bay area to assess exposure to inorganic contaminants. Hepatic Se concentrations were highest in greater scaup (geometric mean = 67 ppm dry weight) and surf scoters (119 ppm) in Suisun Bay, whereas hepatic Hg was highest (19 ppm) in greater scaup and surf scoters from Tomales Bay. Hepatic Se and Hg were lower in ruddy ducks and did not differ between locations. Hepatic supernatants were assayed for enzymes related to glutathione metabolism and antioxidant activity, including glucose-6-phosphate dehydrogenase (G-6-PDH), glutathione peroxidase (GSH peroxidase), glutathione reductase (GSSG reductase), and glutathione-S-transferase (GSH transferase). Glutathione peroxidase activity was higher in surf scoters and ruddy ducks, and G-6-PDH was higher in greater scaup and surf scoters from Suisun Bay than Tomales Bay. Glutathione reductase (GSSG) was higher in SS from Suisun Bay. The ratio of oxidized glutathione (GSSG) to reduced glutathione (GSH) was greater in all species from Tomales Bay. The following significant relationships were found in one or more species with increasing hepatic Hg concentration: lower body, liver, and heart weights; decreased hepatic GSH concentration and G-6-PDH and GSH peroxidase activities; increased ratio of GSSG to GSH; and increased GSSG reductase activity. With increasing hepatic Se concentration, GSH peroxidase increased, but GSH decreased. It is concluded that measurement of associated enzymes in conjunction with thiol status may be a useful bioindicator to discriminate between Hg and Se effects. Concentrations of Hg and Se and the above variables affected have been associated with adverse effects on reproduction and neurological function in experimental studies with mallards.

Hogue, V. E., F. P. Wilkerson, et al. (2005). "Ultraviolet-B Radiation Effects on Natural Phytoplankton Assemblages of Central San Francisco Bay." Estuaries 28(2): 190-203.

Since the discovery of a depletion of the stratospheric ozone layer over Antarctica in 1979, scientific attention has been directed towards the effects of increased doses of ultraviolet radiation on phytoplankton in other ecosystems. Little is known about the effects of ultraviolet-B (280-320 nm) radiation (UVBR) on temperate estuarine phytoplankton. Freshly collected phytoplankton samples from Central San Francisco Bay were exposed to ambient UVBR in quartz bottles and monitored for biomass and nutrient uptake rates for comparison with phytoplankton dispensed into bottles made of polycarbonate that effectively filtered out the UVBR to evaluate response to natural UVBR exposure. Short-term (10-12 h) exposure experiments were carried out monthly from October 1998 to October 1999. No significant effect of UVBR on chlorophyll a concentrations was found but a clear deleterious effect of UVBR on nutrient uptake was observed.

Holland, E., R. Connon, I. Pessah, and I. Werner (2010). The effect of triclosan on whole animal responses and gene transcription in larval fathead minnow (Pimephales promelas). 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Triclosan is an antibacterial agent that has become more and more prevalent in household products since the 1960s. It is not completely removed during waste water treatment leading to contamination of aquatic ecosystems. Triclosan has been shown to occur in waterways around the world, including the San Francisco Bay and Sacramento River, yet its impact on aquatic organisms is not fully understood. We assessed the effects of triclosan on survival, swimming behavior, and neuromuscular and endocrine related gene expression in larval fathead minnow (Pimephales promelas). The nominal 7d chronic median lethal concentration (LC50) was 193 µg.L-1. Triclosan had a significant impact on swimming behavior after just 2h that was consistent after 8h, 24h, and 96 h exposures. Quantitative PCR assessments indicate that triclosan exposure elicits downregulation of the ryanodine receptor (RyR) isoform-1, RyR isoform-3, and Selenoprotein N, which are involved in Ca2+ signaling in either skeletal muscle or the brain. Triclosan also elicited unique endocrine responses in exposed fish. Most notably, fish from lower concentrations had an under expression of Insulin Like Growth Factor (IGF1) while those exposed to 100µg/L had significantly up regulated IGF1. Another gene that showed a similar expression pattern was the VASA homologue, which has a large role in germ cell localization in early embryonic stages and spermatogenesis and oogenesis in adult fish Results from these tests will aid in the development of molecular based biomarkers for triclosan toxicity and will help link molecular effects to whole animal responses. Biomarkers will be used to assess triclosan exposure in fish exposed to Sacramento River water upstream and downstream from a wastewater treatment plant (WWTP) to help determine possible risks in the Sacramento-San Joaquin Delta.

Hollibaugh, J. T., and P.S. Wong (1992). "Ethanol-extractable substrate pools and the incorporation of thymidine L leucine and other substrates by bacterioplankton." Canadian Journal of Microbiology 38(7): 605-613.

Bacterioplankton productivity measurements based on [methyl-3H]-thymidine (TdR) or L-[3,4,5-3H]leucine (L-leu) incorporation typically depend on cold trichloroacetic acid (TCA) precipitation to separate 3H uptake from incorporation. An additional rinse with cold 80% ethanol (EtOH) removed an average of 22 (L-leu) and 32% (TdR) of 3H "incorporated" by San Francisco Bay samples and decreased the between-duplicate difference by a factor of 3.5. Similar results were obtained with samples from Tomales Bay, Calif., and Palmer Station, Antarctica. Varying amounts of cold TCA insoluble radiolabel from six other substrates were removed by the EtOH rinse. Regression analysis showed relationships between the effect of the EtOH rinse and a group of environmental variables and derived parameters. The percentage of 3H removed was generally independent of filter type; however, there were often large differences in the amount of 3H retained by Millipore versus Nuclepore or Poretics filters. The results strongly suggest that an EtOH rinse or other organic extraction should be included in protocols to determine incorporation of radiolabeled substrates into macromolecules. Furthermore, sequestering low molecular weight substrates in some sort of lipid-bound pool may represent a general storage mechanism employed by bacterioplankton.

Hollibaugh, J. T. (1994). "Relationship between thymidine metabolism, bacterioplankton community metabolic capabilities, and sources of organic matter." Microbial Ecology 28(2): 117-131.

Numerous investigations have been directed at verifying and calibrating methods for measuring bacterioplankton production, particularly methods based on the incorporation of thymidine (TdR) into DNA. Careful examination of these data can provide insights into other aspects of the ecology of aerobic heterotrophic microbial communities. Once method-specific biases are eliminated, these measurements indicate that there are broad-scale patterns in the metabolic fate of TdR, differences that seem to reflect broad differences in community metabolic capabilities. Based on work conducted primarily in San Francisco and Tomales Bays, California, I suggest that the metabolic fate of TdR in a given environment may reflect the relative importance to bacterioplankton nutrition of detritus versus fresh phytoplankton carbon. This is probably due to differences in community composition that result from growth on qualitatively different carbon sources. If true, the metabolic fate of TdR may provide a broadly applicable, but simple, index that can be used to assess the relative importance of these general sources of organic matter. Such an index could be very useful in characterizing lacustrine, estuarine, and nearshore environments.

Hollibaugh, J. T., and P.S. Wong (1996). Distribution and activity of bacterioplankton in San Francisco Bay. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science AAAS: 263-288.

Hollibaugh, J. T., Ed. (1996). San Francisco Bay: The Ecosystem. Further Investigations into the Natural History of San Francisco Bay and Delta With Reference to the Influence of Man. San Francisco, CA, American Association for the Advancement of Science.

Hollibaugh, J. T. (1996). San Francisco Bay: The ecosystem. Further investigations into the natural history of San Francisco Bay and delta with reference to the influence of man. San Francisco, American Association for the Advancement of Science.

Hollibaugh, J. T., and P.S. Wong (1999). "Microbial processes in the San Francisco Bay estuarine turbidity maximum." Estuaries and Coasts 22(4): 848-862.

We examined microbial processes and the distribution of particulate materials in the estuarine turbidity maximum (ETM, salinity 2–10 PSS) of northern San Francisco Bay on three cruises during the late spring of 1994 (low flow: April 19, April 28, May 17) and two cruises during the early summer of 1995 (high flow; June 13, July 18). Under low flow conditions, chlorophyll concentrations decreased by a factor of 2–4, bacterial abundance decreased by 20%, and L-leucine incorporation rate decreased by a factor of about 2 over a salinity range of 0–2 PSS, then remained relatively constant at higher salinities. Over this same salinity range under high flow conditions, chlorophyll concentration was c. twofold lower, bacterial abundance was c. threefold higher, and L-leucine incorporation rate was in the same range as during low flow. Under high flow conditions, chlorophyll concentration increased by 20%., bacterial abundance decreased by a factor of 2, and L-leucine incorporation rate decreased by half (June 13) or remained unchanged (July 19) with increasing salinity. Under low flow conditions the concentration of suspended particulate material (SPM), particulate organic carbon (POC), and particulate organic nitrogen (PON) increased 3–10 fold with salinity, to a maximum at intermediate salinities (c. 6 PSS). As a result, the contribution of phytoplankton to POC decreased from a maximum of 32% in fresh water to c. 6% in the ETM. The contribution of bacterial biomass similarly decreased from 5% in fresh water to 0.8% in the ETM. The C:N ratio of particulate material increased from <10 in fresh water to >12 in the ETM. High variability in abundance estimates confounded analysis of patterns in bacterial biomass partitioning between particle-associated and free-living fractions along the salinity gradient. However, the partitioning of L-leucine incorporation shifted dramatically from being predominantly by free-living cells in fresh water to being predominantly by particleassociated populations in the ETM. The metabolic fate of thymidine taken up differed, between particle-associated and free-living bacteria, suggesting some metabolic divergence of these assemblages.

Hollibaugh, J. T., P. S. Wong, et al. (2000). "Similarity of particle-associated and free-living bacterial communities in northern San Francisco Bay, California." Aquatic Microbial Ecology 21: 103-114.

We used denaturing gradient gel electrophoresis (DGGE) of 16S rDNA PCR amplicons to analyze the composition of Bacteria communities in samples collected during the summer, low flow season from northern San Francisco Bay, California. There were clear compositional differences in communities sampled at different locations in the Bay and at different times of the year. Particle-associated (attached) and free-living (free) bacteria in a given sample were generally more similar than communities in different samples. At times, the attached and free communities in a sample appeared identical, suggesting a fairly rapid exchange between them. The free-living community tended to be richer (more operational taxonomic units [OTU] per sample) than the attached community; however, the difference was not statistically significant. Richness declined through the summer. The richest samples were collected on the June cruise (51 OTU sample super(-1)) while the least rich samples were collected on the September cruise (21 OTU sample super(-1)). The number of distinct OTUs encountered in all samples from a cruise ranged from 61 (April) to 45 (October). The greatest number of unique OTUs (26) was found in April samples while the fewest (3) was found in September. There was no consistent hierarchy of richness between samples. Sample groups representing location and size fractions contained from 55 to 61 different OTUs and from 8 to 18 unique (found only once) OTUs. An average of 23% of the OTUs from a given station and size fraction were unique while an average of 5.5% were found on all cruises. Ubiquitous OTUs (found at all stations) ranged from 34% (free-living, June) to 7% (free-living, August) of the distinct OTUs encountered on a given cruise. Our results suggest little difference in the biogeochemical role played by attached versus free bacteria in San Francisco Bay, particularly in the estuarine turbidity maximum. These results are generally consistent with our analyses of the metabolic potential of these communities.

Holmes, A. (2010). Suspended Sediment in San Francisco Bay, Water Years 2008 and 2009. IEP Newsletter. 23: 3.

Hooff, R. C. and S. M. Bollens (2004). "Functional response and potential predatory impact of Tortanus dextrilobatus, a carnivorous copepod recently introduced to the San Francisco Estuary." Marine Ecology Progress Series 277: 167-179.

Despite a dramatic increase in the introduction of non-indigenous estuarine zooplankton in recent decades, the trophic implications of such introductions have rarely been quantified. Here we investigate predation rates of Tortanus dextrilobatus, a carnivorous copepod recently introduced to the San Francisco Estuary that achieves peak abundances in excess of 1000 ind. m(-3). The functional response of T, dextrilobatus feeding upon 2 copepod prey types-the non-indigenous cyclopoid Oithona davisae, and the 'native' calanoid Acartia (Acartiura) sp.-was described by a type II functional response (Ivlev function) at 2 experimental temperatures. In 3 of these 4 treatments, 90 % I-max, was achieved within a naturally occurring range of prey densities. Taxon-specific seasonal size variation was identified, and carbon-based consumption values were used to determine temperature-dependent rates of predation on both prey types. These empirically derived consumption rates and temperature dependence values were then applied to broadscale surveys (1997 to 1999) of zooplankton community composition in order to estimate the predatory impact of T. dextrilobatus upon prey populations in the San Francisco Estuary. Predatory impact estimates (% population consumed d(-1)) greater than 1 % occurred on a regular basis when T. dextrilobatus was abundant, with maxima exceeding 20, 65, and 25% for O. davisae, Acartia (Acartiiura) sp. and all Copepoda, respectively. These observations support the hypothesis that non-indigenous invertebrate zooplanktivores can play a significant role, at least seasonally or episodically, in the secondary production dynamics of aquatic ecosystems.

Hoogeweg, G., M. Williams, R. Breuer, D. Denton, M. Zhang, S. Hecht, Y. Lou, and D. Ficklin (2010). Spatial and temporal quantification of pesticide loadings to the Sacramento River, San Joaquin River, and Bay-Delta to guide risk assessment for sensitive species—Part I: Project status. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

A weight-of-evidence analysis is being conducted to identify major sources of pesticide loadings to the Sacramento River, San Joaquin River, and Bay-Delta estuary. The objectives of this analysis are to improve decision making and optimize resource spending in understanding and mitigating pesticide exposure to sensitive and endangered species across a number of federal, state, and regional water quality programs. Results from this project are being used to: 1) provide further knowledge of the fate and transport of agricultural chemicals (e.g., copper, organophosphates) and emerging pesticides (e.g., pyrethroids); 2) match results to the location of sensitive species critical habitats; 3) identify and rank pesticide source areas; 4) evaluate implications of future pesticide use trends and changes in climatic conditions; 5) aid in developing plans to improve ecosystem quality and water quality by strategic placement of BMPs and hydrologic operations; 6) support future monitoring programs (strategic locations, sampling frequency); 7) link results to life cycle models currently under development for striped bass and delta smelt, as well as existing models for salmonids; and 8) provide a data-link to support other water quality models and population models.

Hopkins, T. E., and J.J. Cech Jr. (1992). "Physiological effects of capturing striped bass in gill nets and fyke traps." Transactions of the American Fisheries Society 121(6): 819-822.

Adult striped bass Morone saxatilis were captured in 20–40-min gill-net sets in the San Joaquin River, California, and in 24–48-h fyke-trap sets in the Sacramento River as part of a tagging program. They were bled by cardiac puncture for various measurements of stress responses to capture and handling. Fish caught in gill nets were more lethargic, were kept longer out of water, and were significantly more acidotic (lower blood pH and higher lactate concentration) than fyke-trapped fish. Gillnetted fish also had a significantly higher Pco2, hematocrit, and plasma glucose and potassium concentrations than fyke-trapped fish. Both capture methods induced secondary stress responses, but responses were greater in gillnetted fish, probably because gill nets restricted buccal and opercular movements.

Hornberger, M. I., S.N. Luoma, A. van Geen, C. Fuller, and R. Anima (1999). "Historical trends of metals in the sediments of San Francisco Bay, California." Marine Chemistry 64(1-2): 39-55.

Concentrations of Ag, Al, Cr, Cu, Fe, Hg, Mn, Ni, Pb, V and Zn were determined in six sediment cores from San Francisco Bay (SFB) and one sediment core in Tomales Bay (TB), a reference estuary. SFB cores were collected from between the head of the estuary and its mouth (Grizzly Bay, GB; San Pablo Bay, SP; Central Bay, CB; Richardson Bay, RB, respectively) and ranged in length from 150 to 250 cm. Concentrations of Cr, V and Ni are greater than mean crustal content in SFB and TB sediments, and greater than found in many other coastal sediments. However, erosion of ultramafic rock formations in the watershed appears to be the predominant source. Baseline concentrations of other metals were determined from horizons deposited before sediments were influenced by human activities and by comparing concentrations to those in TB. Baseline concentrations of Cu co-varied with Al in the SFB sediments and ranged from 23.7±1.2 μg/g to 41.4±2.4 μg/g. Baseline concentrations of other metals were less variable: Ag, 0.09±0.02 μg/g; Pb, 5.2±0.7 μg/g; Hg, 0.06±0.01 μg/g; Zn, 78±7 μg/g. The earliest anthropogenic influence on metal concentrations appeared as Hg contamination (0.3–0.4 μg/g) in sediments deposited at SP between 1850 and 1880, apparently associated with debris from hydraulic gold mining. Maximum concentrations of Hg within the cores were 20 times baseline. Greater inventories of Hg at SP and GB than at RB verified the importance of mining in the watershed as a source. Enrichment of Ag, Pb, Cu and Zn first appeared after 1910 in the RB core, later than is observed in Europe or eastern North America. Maximum concentrations of Ag and Pb were 5–10 times baseline and Cu and Zn concentrations were less than three times baseline. Large inventories of Pb to the sediments in the GB and SP cores appeared to be the result of the proximity to a large Pb smelter. Inventories of Pb at RB are similar to those typical of atmospheric inputs, although influence from the Pb smelter is also suspected. Concentrations of Hg and Pb have decreased since the 1970s (to 0.30 μg/g and 25 μg/g, respectively) and were similar among all cores in 1990. Early Ag contamination was perhaps a byproduct of the Pb smelting process, but a modern source of Ag is also indicated, especially at RB and CB.

Hornberger, M. I., S. N. Luoma, et al. (2000). "Linkage of bioaccumulation and biological effects to changes in pollutant loads in south San Francisco Bay." Environmental Science and Technology 34: 2401-2409.

The developed world has invested billions of dollars in waste treatment since the 1970s; however, changes in ecological or biological responses are rarely associated with reductions in metal pollutants. Here we present a novel, 23-yr time series of environmental change from a San Francisco Bay mudflat located 1 km from the discharge of a suburban domestic sewage treatment plant. Samples of surface sediment, the bioindicator Macoma balthica, and metals loading data were used to establish links between discharge, bioaccumulation, and effects. Mean annual Ag concentrations in M. balthica were 106 mu g/g in 1978 and 3.67 mu g/g in 1998.

Concentrations of Cu declined from 287 mu g/g in 1980 to a minimum of 24 mu g/g in 1991. Declining; Cu bioaccumulation was strongly correlated with decreasing Cu loads from the plant between 1977 and 1998. Relationships with bioaccumulation and total annual precipitation suggested that inputs from nonpoint sources were most important in controlling Zn bioavailability during the same period. Ecoepidemiological criteria were used to associate failed gamete production in M balthica to a metals-enriched environment. Reproduction persistently failed between the mid-1970s and mid-1980s; it recovered after metal contamination declined. Other potential environmental causes such as food availability, sediment chemistry, or seasonal salinity fluctuations were not related to the timing of the change in reproductive capability. The results establish an associative link, suggesting that it is important to further investigate the chemical interference of Cu and/or Ag with invertebrate reproduction at relatively moderate levels of environmental contamination

Hostettler, F. D., Rapp, J. B., Kvenvolden, K. A., and Luoma, S. N. (1989). "ORGANIC MARKERS AS SOURCE DISCRIMINANTS AND SEDIMENT TRANSPORT INDICATORS IN SOUTH SAN-FRANCISCO BAY, CALIFORNIA." Geochimica et Cosmochimica Acta 53(7): 1563-1576.

Hostettler, F. D., J.B. Rapp, and K.A. Kvenvolden (1992). "Use of geochemical biomarkers in bottom sediment to track oil from a spill, San Francisco Bay, California." Marine Pollution Bulletin 24(1): 15-20.

In April 1988, approximately 1500 m3 of a San Joaquin Valley crude oil were accidentally released from a Shell Oil Co. refinery near Martinez, Californa. The oil flowed into Carquinez Strait and Suisun Bay in northern San Francisco Bay. Sediment and oil samples were collected within a week and analysed for geochemical marker compounds in order to track the molecular signature of the oil spill in the bottom sediment. Identification of the spilled oil in the sediment was complicated by the degraded nature of the oil and the similarity of the remaining, chromatographically resolvable constituents to those already present in the sediments from anthropogenic petroleum contamination, pyrogenic sources, and urban drainage. Ratios of hopane and sterane biomarkers, and of polycyclic aromatic hydrocarbons and their alkylated derivatives best identified the oil impingement. They showed the oil impact at this early stage to be surficial only, and to be patchy even within an area of heavy oil exposure.

Hostettler, F. D., W.E. Pereira, K.A. Kvenvolden, A. van Geen, S.N. Luoma, C.C. Fuller, and R. Anima (1999). "A record of hydrocarbon input to San Francisco Bay as traced by biomarker profiles in surface sediment and sediment cores." Marine Chemistry 64(1-2): 115-127.

San Francisco Bay is one of the world's largest urbanized estuarine systems. Its water and sediment receive organic input from a wide variety of sources; much of this organic material is anthropogenically derived. To document the spatial and historical record of the organic contaminant input, surficial sediment from 17 sites throughout San Francisco Bay and sediment cores from two locations—Richardson Bay and San Pablo Bay—were analyzed for biomarker constituents. Biomarkers, that is, ‘molecular fossils', primarily hopanes, steranes, and n-alkanes, provide information on anthropogenic contamination, especially that related to petrogenic sources, as well as on recent input of biogenic material. The biomarker parameters from the surficial sediment and the upper horizons of the cores show a dominance of anthropogenic input, whereas the biomarker profiles at the lower horizons of the cores indicate primarily biogenic input. In the Richardson Bay core the gradual upcore transition from lower maturity background organics to a dominance of anthropogenic contamination occurred about 70–100 years ago and corresponds to the industrial development of the San Francisco Bay area. In San Pablo Bay, the transition was very abrupt, reflecting the complex depositional history of the area. This sharp transition, perhaps indicating a depositional hiatus or erosional period, dated at pre-1952, is clearly visible. Below, the hiatus the biomarker parameters are immature; above, they are mature and show an anthropogenic overlay. Higher concentrations of terrigenous n-alkanes in the upper horizons in this core are indicative of an increase in terrigenous organic matter input in San Pablo Bay, possibly a result of water diversion projects and changes in the fresh water flow into the Bay from the Delta. Alternatively, it could reflect a dilution of organic

material in the lower core sections with hydraulic mining debris.

Hothem, R. L. and D. Hatch (2004). "Reproductive Success of the Black-crowned Night Heron at Alcatraz Island, San Francisco Bay, California, 1990-2002." Waterbirds 27(1): 112-125.

Nesting chronology, habitat use, subcolony use, and hatchability were documented for the Black-crowned Night Heron (Nycticorax nycticorax) nesting at Alcatraz Island, San Francisco Bay, California during 1990-2002. Reproductive success was estimated using the Mayfield method and compared among years. Totals of monitored nests per year ranged from 68 in 2001 to 341 in 1996, with a trend of declining numbers since 1996. An increase in numbers of the Western Gull (Larus occidentalis), the Black-crowned Night Heron's primary competitor, occurred during the same period. Overall reproductive success of the Black-crowned Night Heron at Alcatraz Island was below the 13-year average of 56.4% since 1996. During the study, the average number of chicks fledged per nest each year ranged from 0.46 to 1.27, which is less than the two chicks per nest suggested as a requirement for a sustained population. Embryos in five of 187 failed Black-crowned Night Heron eggs were deformed. In 1990 and 1991, eggs were analyzed for a wide range of contaminants, but none appeared to be sufficiently elevated to have caused the observed deformities. Based on these relatively low levels of contaminants, a high hatchability rate (94.5%), and relatively low levels of embryotoxicity, contaminants did not appear to significantly affect Black-crowned Night Heron reproduction at Alcatraz Island. However, predation by the Common Raven (Corvus corax) and Western Gull, interspecific competition with the Western Gull, habitat deterioration, and possible human disturbance are likely factors contributing to the decline in Black-crowned Night Heron reproductive success on Alcatraz Island in recent years.

Hothem, R. L., D. G. Lonzarich, et al. (1998). "Contaminants in wintering canvasbacks and scaups from San Francisco Bay, California." Environmental Monitoring and Assessment 50(1): 67-84.

Organochlorines, metals, and trace elements were measured in liver, kidney, or whole-body tissues of canvasbacks (Aythya valisineria), lesser scaups (A. affinis), and greater scaups (A. marila) collected from San Francisco Bay and three coastal areas of California during the winter of 1986-1987. Potentially toxic concentrations of mercury (mean less than or equal to 10.4 mu g/g, dry weight) and selenium (mean less than or equal to 32.7 mu g/g, dry weight) were found in livers of scaups and canvasbacks from several San Francisco Bay sites These elements varied spatially, temporally, and between species, with the highest concentrations found in late winter. Mean concentrations of mercury, selenium, and cadmium were generally higher in scaups than in canvasbacks. Of all the organochlorines included in the analyses, only p,p'-DDE and total PCBs were detected in all samples in this study. Mean whole-body concentrations of DDE and PCBs from San Francisco Bay ducks collected in late winter varied spatially and between species, but the concentrations were not considered toxic. Causes for inter-specific differences are unclear, but may be attributable to differences in diet, movement, or physiology.

Hothem, R. L., D. L. Roster, et al. (1995). "Spatial and temporal trends of contaminants in eggs of wading birds from San Francisco Bay, California." Environmental Toxicology and Chemistry 14(8): 1319-1331.

Between 1989 and 1991, reproduction by black-crowned night-herons (Nycticorax nycticorax) and snowy egrets (Egretta thula) was studied at sites in San Francisco Bay. Eggs were collected from these and other bay sites and from South Wilbur Flood Area, a reference site in California's San Joaquin Valley. Eggs were analyzed for inorganic trace elements, organochlorine pesticides, and polychlorinated biphenyls (PCBs). Results were compared among sites and years and with results of previous studies. There was some evidence of impaired reproduction, but concentrations of contaminants were generally lower than threshold levels for such effects. Egg hatchability was generally good, with predation being the factor that most limited reproductive success. Mean PCB concentrations were generally higher in eggs from the south end of San Francisco Bay than from the north, but the only temporal change, an increase, was observed at Alcatraz Island. There were spatial differences for p,p'-DDE in night-heron eggs in 1990, but the highest mean concentration of DDE was in night-heron eggs from South Wilbur in 1991. Temporal declines in maximum concentrations of DDE in eggs were observed in the bay, but means did not change significantly over time. At Bair Island in the southern end of the bay, mean concentrations of mercury decreased while selenium increased in night-heron eggs over time, but there were no clear bay-wide spatial or temporal trends for either element.

Howard, J. (2010). The other clams: Native freshwater species in California. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Howe, E. R. and C. A. Simenstad (2007). "Restoration trajectories and food web linkages in San Francisco Bays estuarine marshes: a manipulative translocation experiment." Marine Ecology Progress Series 351: 65-76.

We measured delta super(13)C, delta super(15)N and delta super(34)S signatures of natural and translocated mussels Ischadium demissum to identify food web source differences among estuarine marshes displaying various stages of restorative development. We hypothesized that mussels inhabiting younger marshes would be more dependent on allochthonous organic matter sources, while those inhabiting mature marshes would depend on autochthonous sources. Mussels collected from an undisturbed (reference) marsh located within the Napa River estuarine complex in San Francisco Bay were translocated to a series of restoring marsh sites located within the same river system. The isotopic composition of naturally growing mussels was compared with translocated mussels, which were incubated in restoring sites for 5 and 7 mo. Measurements of delta super(13)C, delta super(15)N, and delta super(34)S indicated differences in food web sources supporting I. demissum among the 4 marsh sites. A strong cage effect was detected during the initial 5 mo collection interval, indicating that translocated mussels had yet to equilibrate with their new environments. Multiple source mixing model analysis indicated that C sub(3) emergent vascular plants and brackish phytoplankton contributed most of the organic matter consumed by I. demissum over both time periods, but that mussels collected from the downstream sites exhibited higher dependence upon vascular plant detritus. Bay produced phytoplankton contributed very little to I. demissum diets, suggesting that the pelagic waters of San Francisco Bay have less influence on marsh food web dynamics than previously anticipated. The results of this experiment show that food web pathways are strongest at intermediate scales; they can be relatively short and unique to specific marshes along the estuarine gradient, but similarities in mussel diets among marshes in close proximity to one another suggests inter-marsh exchange of organic matter. It is, therefore, likely that food webs in young restoration sites depend upon organic matter subsidies from neighboring marshes, rather than from San Francisco Bay.

Hrodey, P., and C.A. Simenstad (2010). The Breach III study: 1 year down, 2 years still to come - What we have learned so far and where we hope to be at the end. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Liberty Island has been recognized by researchers, agency work teams and planning processes as refugia for native fish species, a potential source of turbidity and organic matter inputs, and for its hydrodynamic influence within the north delta region. The Breach III study hopes to further inform the planning and decision making process by providing a predictive level of understanding about: 1) how abiotic and biotic factors in a restoring (levee breach) wetland control vegetation colonization and expansion and subsequent responses by native fish and wildlife; 2) the geomorphic and other thresholds that regulate the processes of marsh development; and, 3) how restoration processes influence local flooding and levee erosion over the course of restoration. Since December 2009, our research team has been collecting data for several model inputs including fish and macroinvertebrates assemblages, food web dynamics, primary productivity, vegetation colonization and elevation, sediment accretion and geomorphology, water quality, and wind and wave climates. This presentation will serve to wrap-up the Cache Slough Complex Special Session and highlight some of our preliminary results as well as describe the modeling and synthesis activities that will take place during the remainder of our study. Finally, we will discuss our expected work products and the management tools we propose to develop. Defining these unique wetlands, understanding how they develop, and how they contribute to the surrounding environment are important factors that need to be considered during the planning and management of large-scale restoration projects in the Sacramento – San Joaquin River Delta. The ultimate goal of Breach III is to provide us with our first predictive, modeling tools that integrate this understanding. Given the amount of restoration projects already underway or slated to start in the near term, it is imperative that resource managers have the tools necessary to make informed decisions to base their actions upon.

Huang, S., A. Strathe, W. Wang, F. James, D. Deng, R. Boston, and S. Hung (2010). A kinetic analysis of Se uptake, distribution, and excretion in white sturgeon. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

A novel combined technique of stomach intubation, dorsal aorta cannulation and urinary catheterization was used to characterize the 48 hr kinetics of common Se forms at an ecologically relevant dose (500 ug/ kg body weight) in juvenile white sturgeons. Selenium in the forms of selenite, selenocysteine (SeCys), selenomethionine (SeMet), Se-methylselenocysteine (MSeCys) or selenoyeast (SeYeast) were orally intubated into groups of five white sturgeons. Blood and urine were collected through-out and tissues were taken at 48 hr for total Se analysis. A five compartmental model was developed for describing Se uptake, distribution and excretion - gut; two blood pools (protein and non-protein bound Se); tissue; and urine. All fluxes were based on mass-action kinetics. The model has six structural parameters: rates constants for absorption (ka), transfer between blood pools (k32, k24), body tissue (k42) and urine (ke) and a blood volume parameter (vol). The control fish were used as a baseline for tissue Se level for all fish but were not used in the kinetic analysis. The data analysis was undertaken in WinBUGS using the Wbdiff ordinary differential equation solver interface. The statistical model was specified as a three level hierarchy: the first described the within fish variability; the second described the between fish variability; and the third specified the non-informative priors for all parameters expect for the volume, which was established from literature. The posterior means for the population mean parameters are: 0.022 (SE = 0.00292) h-1, 1.6 (SE = 0.14) h-1, 0.0041 (SE = 9.89E-4) h-1, 0.27 (SE = 0.0345), 0.011 (SE = 0.00144) h-1, 37.6 (SE = 5.43) ml for ka k32, k42, k24, ke, and vol, respectively. From our model, we have showed that the uptake, distribution and excretion of Se are significantly different among forms and Se is preferentially distributed into metabolically active tissues. Urinary excretion of Se was also found to be form dependent.

Hughes, S. (2010). Understanding the strategies and decision making of California’s urban water agencies. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

California’s growing population has long been a driver of water management decisions, and a competing user for scarce water resources. Today, efforts to adapt water use patterns in cities have become a cornerstone of water policies, such as Governor Schwarzenegger’s ‘20x2020’ proposal. However, little work has been done to systematically characterize and analyze the decisions urban water agencies make about water production and distribution. A new database using the California Department of Water Resource’s Public Water System Survey is used, for the first time, to further our understanding in these critical areas of water management. This presentation includes the following analytical results: (1) a description of urban water use and distribution patterns throughout the state, (2) how these patterns result in different types of strategies for water agencies, and (3) what we can learn from these patterns about the effectiveness of various water production strategies in urban water agencies. These results have significant implications as they use new data to improve our understanding of strategy and decision making in urban water agencies, and suggest ways that policy reforms and planning efforts may be more effective in the future.

Hui, C. A., J. Y. Takekawa, et al. (2001). "Contaminant profiles of two species of shorebirds foraging together at two neighboring sites in south San Francisco Bay, California." Environmental Monitoring and Assessment 71(2): 107-121.

The San Francisco Bay estuary is used by over one million shorebirds during spring migration and is home to several hundred thousand during the winter. Most shorebird use occurs in the southern reach of the estuary (South Bay). The reduced water circulation and discharge from industrial sources in the South Bay are responsible for the highest levels of some trace elements in the estuary. Wintering shorebirds have been found to have strong site fidelity to areas as small as a few kilometers in the South Bay, which may increase their exposure to contaminants near local point sources. In addition, different shorebird species foraging at the same site have been shown to have different contaminant burdens. Thus, our objectives were to test whether contaminant burdens differed by species, or whether contaminant burdens differed in shorebirds collected at adjacent sites. We examined the contaminant profiles of two species of shorebirds, long-billed dowitchers (Limnodromus scolopaceus) and western sandpipers (Calidris mauri) that forage together at two sites, Hayward and Newark, separated by 8 km in the South Bay. We used multivariate analysis of variance tests to compare the composition of 14 elemental analytes in their liver tissues and estimated their molar ratios of Hg and Se. Composite samples were used for contaminant analyses because of the small body size of the shorebirds. Seven elemental analytes (Ag, Ba, Be, Cr, Ni, Pb, V) were below detection limits in a majority of the samples so statistical analyses were precluded. In the measurable analytes (As, Cd, Cu, Hg, Mn, Se, Zn), we found no significant intra-site differences of contaminant profiles for the two species. We pooled the samples to examine inter-site differences and found significant differences in contaminant profiles between shorebirds at the neighboring sites ($P = 0.03$). Shorebirds at Newark had higher ($P < 0.05$) concentrations of As, Cd, and Se than those at Hayward. Dowitchers at Newark had concentrations of Hg and Se which were highly correlated ($P < 0.003$) in a mean molar ratio of 1:19, similar to that reported in other birds. In the larger dowitcher species, we also examined exposure to 20 organochlorine compounds. Organic analyses showed that the dowitchers had been exposed to DDE, PCBs, dieldrin and trans-nonachlor, but with no significant differences in concentrations between Hayward and Newark ($P > 0.05$).

Hunsaker, C. T., and DG. Neary (2011). Sediment loads and erosion in forest headwater streams of the Sierra Nevada, California. Revisiting Experimental Catchment Studies in Forest Hydrology, IAHS Publ. 353 Melbourne, Australia, IAHS Press.
Defining best management practices for forests requires quantification of the variability of stream sediment loads for managed and unmanaged forest conditions and their associated sediment sources. Although “best management practices” are used, the public has concerns about effects from forest restoration activities and commercial timber harvests. It is necessary to know the current and/or natural range of variability to be able to determine if management activity has a significant negative impact; only long-term research can provide such data. The Forest Service in the United States has such long-term watershed research. An annual sediment load from a watershed is determined by emptying a sediment basin located in the stream channel at the end of a water year. Sediment fences, stream bank pins, survey techniques, and turbidity sensors provide measurements that can be used to determine the sources of sediment. The importance of having an undisturbed watershed for “natural range of variability” to compare with watersheds previously or currently under active management is illustrated. For example, at the Kings River Experimental Watersheds one of the managed watersheds in the rain and snow zone, produced 1.8, 15.2, and 18.7 kg/ha for water years 2004, 2005, and 2006, respectively. The increase in sediment accumulation correlates with an increase in yearly precipitation. The undisturbed watershed and the snow-dominated watersheds produce similar, and sometimes higher, sediment loads for these same years.

Hunsaker, C. T., T.W. Whitaker, and R.C. Bales (2012). "Snowmelt runoff and water yield along elevation and temperature gradients in California’s southern Sierra Nevada." Journal of the American Water Resources Association 48(4): 12.
Differences in hydrologic response across the rain-snow transition in the southern Sierra Nevada
were studied in eight headwater catchments – the Kings River Experimental Watersheds – using continuous
precipitation, snowpack, and streamflow measurements. The annual runoff ratio (discharge divided by precipitation)

increased about 0.1 per 300 m of mean catchment elevation over the range 1,800-2,400 m. Higher-elevation
catchments have lower vegetation density, shallow soils with rapid permeability, and a shorter growing season
when compared with those at lower elevations. Average annual temperatures ranged from 6.8┐C at 2,400 m to
8.6 at 1,950 m elevation, with annual precipitation being 75-95% snow at the highest elevations vs. 20-50% at
the lowest. Peak discharge lagged peak snow accumulation on the order of 60 days at the higher elevations and
20 to 30 days at the lower elevations. Snowmelt dominated the daily streamflow cycle over a period of about
30 days in higher elevation catchments, followed by a 15-day transition to evapotranspiration dominating the
daily streamflow cycle. Discharge from lower elevation catchments was rainfall dominated in spring, with the
transition to evapotranspiration dominance being less distinct. Climate warming that results in a longer growing
season and a shift from snow to rain would result in earlier runoff and a lower runoff ratio.

Hunt, S. L., T. J. Mulligan, et al. (1999). "Oceanic feeding habits of chinook salmon, Oncorhynchus tshawytscha, off northern California." Fishery Bulletin 97(3): 717-721.

The chinook salmon, Oncorhynchus tshawytscha, is an important commercial and recreational species inhabiting rivers and nearshore coastal waters from San Diego, California, to the Bering Sea and Japan (Miller and Lea, 1972). Many West Coast populations are in a serious decline (Pearcy, 1992). Nehlsen et al. (1991) reported an overall decrease in salmonid numbers in the coastal waters of the Pacific Northwest and suggested that northern California chinook salmon runs may be at high risk of extinction owing to 1) habitat damage and mainstream passage problems; 2) overharvesting; and 3) hybridization, predation, competition, disease, and poor ocean survival conditions. Surprisingly, little research has been done off the northern California coast regarding the diet of salmonids during oceanic migrations.

Hunter, Y. R. and J. S. Kuwabara (1994). "IONIC-STRENGTH AND DOC DETERMINATIONS FROM VARIOUS FRESH-WATER SOURCES TO THE SAN-FRANCISCO BAY." Bulletin of Environmental Contamination and Toxicology 52(2): 311-318.

Hutchinson, A. (1982). Plankton studies in San Francisco Bay. 3. Zooplankton species composition and abundance in the South Bay, 1980-81. Menlo Park, CA, U.S. Geological Survey: 135.

Huzzey, L. M., J.E. Cloern, and T.M. Powell (1990). "Episodic changes in lateral transport and phytoplankton distribution in south San Francisco Bay (California, USA)." Limnology and Oceanography 35(2): 472-478.

Observations in South San Francisco Bay during 1982 showed that substantial cross-channel, nontidal flows accompanied episodic increases in the longitudinal, nontidal flows. Along the channel the nontidal circulation was enhanced during the monthly minima in tidal energy or as a result of wind forcing, producing up-estuary flows 2-3 times greater than normal. These longitudinal pulses modified the horizontal and vertical salinity distributions and regerated cross-channel flows of up to 0.07 m s-1 that persisted for several days. The increased lateral flows were directed to the west and may explain the large fluctuations in phytoplankton biomass observed over the broad eastern shoal during spring.

Hwang, H. (2010). Sediment quality assessment in tidal salt marshes in northern California: An evaluation of multiple lines of evidence approach. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

This study evaluated the efficacy of integrating a traditional sediment quality triad approach with selected sublethal chronic indicators in resident species in assessing the quality of sediments in four tidal salt marshes. These

included the highly contaminated (Stege Marsh) and relatively clean (China Camp) marshes in San Francisco Bay and two reference marshes in Tomales Bay in California, USA. Two components (toxicity potential of sedimentary contaminants and benthic macroinvertebrate survey) of the sediment quality triads showed significant differences between Stege Marsh and reference marshes. Some sublethal chronic toxicity tests such as apoptotic DNA fragmentation in liver cells of longjaw mudsucker (Gillichthys mirabilis) and embryo abnormality in lined shore crab (Pachygrapsus crassipes) also clearly distinguished contaminated and reference marshes. The present study demonstrates that additional chronic sublethal responses measured in resident species under field exposure conditions can be readily combined with traditional sediment quality triads for an expanded multiple lines of evidence approach. This confirmatory step may be warranted in environments like salt marshes in which positive interferences affect interpretation of toxicity test data. Integration of the portfolio of responses in resident species can support a more comprehensive and informative sediment quality assessment in salt marshes and possibly other habitat types as well.

Hwang, H.-M., P. G. Green, et al. (2006). "Tidal salt marsh sediment in California, USA. Part 1: Occurrence and sources of organic contaminants." Chemosphere 64(8): 1383-1392.
Surface sediment samples (0-5cm) from five tidal marshes along the coast of California, USA were analyzed for organic pollutants to investigate their relationship to land use, current distribution within marshes, and possible sources. Among the study areas, Stege Marsh, located in San Francisco Bay, was the most contaminated. Compared to San Francisco Bay, Stege Marsh had much higher levels of organic contaminants such as PCBs (polychlorinated biphenyls), DDTs, and chlordanes. At reference marshes (Tom's Point and Walker Creek in Tomales Bay), organic contaminants in sediments were very low. While PAHs (polycyclic aromatic hydrocarbons) were found at all of the study areas (22-13600ngg-1), measurable concentrations of PCBs were found only in the sediments from Stege Marsh (80-9940ngg-1). Combustion related (pyrogenic) high molecular weight PAHs were dominant in sediments from Stege and Carpinteria Marshes, while in sediments from Tom's Point and Walker Creek petroleum related (petrogenic) low molecular weight PAHs and alkyl-substituted PAHs were much more abundant than pyrogenic PAHs. PCB congener patterns in all of the Stege Marsh samples were the same and revealed that Aroclor 1248 was a predominant source. In all marshes, the sum of DDE and DDD accounted for more than 90% of total DDTs, indicating that DDT has degraded significantly. The ratios of p,p'-DDE to p,p'-DDD in sediments from Stege Marsh provide evidence of possible previous use of technical DDD. Chlordane ratios indicated that chlordanes have degraded slightly. Bis(2-ethylhexyl)phthalate (280-32000ngg-1) was the most abundant phthalate. The data indicates that Stege Marsh may be a source of contaminants that continue to be discharged into San Francisco Bay.

Hymanson, Z., D. Mayer, et al. (1994). Long-term trends in benthos abundance and persistence in the upper Sacramento-San Joaquin estuary. Summary report: 1980-1990. Sacramento CA, Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 38.

Hymanson, Z. P. (1991). Results of a spatially intensive survey for Potamocorbula amurensis in the upper San Francisco Bay estuary. Sacramento CA, Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 38.

Ignoffo, T., W.J. Kimmerer, and A. Gould (2010). The growth and development of calanoid copepods in the food limited San Francisco Estuary. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The low-salinity zone (LSZ) of the San Francisco Estuary is a region of low primary productivity and a preponderance of introduced species of copepods. In recent years there has been a decline in the abundances of several pelagic fish species and mesozooplankton that inhabit this region, and the decreased primary productivity could be a contributing factor. We investigated the foodweb of this region, with the aim of understanding its function and its potential role in the

fish decline. We calculated the growth rates of copepods to determine their response to reduced primary production, the flow of carbon through the foodweb, and the role of copepods as a food source for pelagic fishes. Growth rate experiments were conducted in spring-summer 2006-2007 on the calanoid copepods present in the LSZ, Eurytemora affinis, Pseudodiaptomus forbesi, and Acartiella sinensis. Growth was measured in terms of carbon, and development was noted by passage from one stage to the next. All species had growth rates around 0.08/day, much lower than potential growth rates of about 0.3/day for these copepods at food-saturated growth rates. Differences in primary production between wet and dry years during our study were reflected in rates of copepod growth. The cyclopoid copepod Limnoithona tetraspina showed signs of food limitation with low growth rates (0.024/day), yet it remains the most abundant copepod in the LSZ suggesting low mortality rates. The decrease in the abundance of calanoid copepods may be due to the low availability of food, competition for that food with the abundant L. tetraspina, and consumption of nauplii by the clam Corbula amurensis. By understanding the role of calanoid copepods in the foodweb of this food-limited estuary we hope to understand the influence of low productivity in the foodweb on the ongoing decline of pelagic fishes.

Ingersoll, C. G., F.J. Dwyer, and T.W. May (1990). "Toxicity of inorganic and organic selenium to Daphnia magna (Cladocera) and Chironomous riparius (Diptera)." Environmental Toxicology and Chemistry 9(9): 1171-1182.
Elevated concentrations of selenium (Se) have been previously measured in biota sampled from the Kesterson National Wildlife Refuge (KNWR) in the San Joaquin Valley of central California. We conducted acute and chronic toxicity tests with the cladoceran Daphnia magna and the midge Chironomus riparius to determine the toxicity or bioaccumulation of waterborne Se in a reconstituted water similar to the San Joaquin River. Daphnids were more acutely sensitive than midges to the toxic effects of inorganic Se. An organic form of Se (seleno-[L]-methionine) was extremely toxic to daphnids, but was relatively nontoxic to midges. In long-term exposure to a 6:1 mixture of selenate to selenite (a mixture representative of KNWR), the emergence time of adult midges was delayed at Se concentrations ≥ 837 µg/L. Daphnid reproduction and intrinsic rate of natural increase (r) were reduced at Se concentrations ≥ 348 µg/L and growth of adults was reduced at ≥ 156 µg/L. Whole body Mg, K and Na concentrations in daphnids were not affected by chronic Se exposure; however, whole body Ca concentration increased at intermediate Se exposure concentrations. In addition, whole body Cl concentration was reduced at 711 µg Se/L. Daphnids accumulated potentially toxic concentrations of Se from water that may adversely affect fish or waterfowl through the food chain.

Ingram, B. L., J.C. Ingle, and M. E. Conrad (1996). Isotopic records of pre-historic salinity and river inflow in San Francisco Bay Estuary. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, Pacific Division, American Association for the Advancement of Science
AAAS: 35-61.

Ingram, B. L. (1998). "Differences in radiocarbon age between shell and charcoal from a Holocene shellmound in northern California." Quaternary Research 49(1): 102-110.
The West Berkeley shellmound, the oldest well-dated archaeological site in the San Francisco Bay region, contains shell and charcoal ranging in age from ca. 1200 to 5700 cal yr B.P. Radiocarbon bon ages of marine shell and charcoal collected from fifteen stratigraphic levels in the West Berkeley shellmound suggest changes in the C-14 content of San Francisco Bay surface waters relative to the atmosphere (the oceanic reservoir age) over the past 5000 yr. The reservoir age of San Francisco Play waters fluctuated between 870 and -170 C-14 yr over the past 5000 yr, with the lowest values occurring 2900 to 3800 cal yr B.P. and the highest values between 1200 and 2000 cal yr B.P. Changes in the radiocarbon reservoir age may be due to changes in the strength of seasonal wind-driven upwelling off coastal California, where upwelling brings C-14-depleted waters to the surface. The period of lowest Delta R values (at 3500 to 3900 cal yr B.P.) is coincident with relatively low salinity in San Francisco Bay (indicating high freshwater inflow) and wet climate in California based on lake level records. The period of high Delta R values (1200-2000 cal yr

B.P.) is coincident with one of the driest periods in California during the late Holocene. These data suggest a link between coastal upwelling and precipitation over central California The age of the top of West Berkeley mound and several other mounds in the San Francisco Bay region (1100 to 1300 cal yr B.P.) coincides with a prolonged dry period in California and low river inflow to San Francisco Bay. Perhaps the sites were abandoned because of the drought. (C) 1998 University of Washington.

Ingram, B. L., M. E. Conrad, et al. (1996). "Stable isotope and salinity systematics in estuarine waters and carbonates: San Francisco Bay." Geochimica et Cosmochimica Acta 60(3): 455-467.

Salinities, delta D and delta super(18)O values of water samples collected bimonthly from two stations in San Francisco Bay estuary during 1991-1993, and along a salinity transect in March of 1992, indicate a linear mixing relation between the isotopic compositions of the waters and their salinities. The salinities and stable isotope compositions of samples from two locations in San Francisco Bay vary in response to changes in freshwater inflow. The data from these locations indicate simple mixtures of Pacific Ocean water (salinity approximately 33, delta super(18)O approximately 0 to -1ppt, delta D approximately 0 to -10ppt) and Sacramento-San Joaquin River water (salinity approximately 0, delta super(18)O = -10 to -12ppt, delta D = -75 to -85ppt). Preliminary water balance estimates, using isotopic differences between local and upland runoff, suggest that local runoff (including waste water) comprises less than 20% of total freshwater entering the bay. The average delta super(18)O values of mussel shells (Mytilus edulis) collected live from eight locations in San Francisco Bay primarily reflect the delta super(18)O of the water in which they grew. Shells subsampled along growth bands show that seasonal shifts in salinity and delta super(18)O are recorded in the shells. Therefore, the use of stable isotope measurements should be useful in reconstructing pre-instrumental bay salinity and associated freshwater inflow (both annual average values and seasonal variations) to the San Francisco Bay, as well as potentially other estuarine systems.

Ingram, B. L., P. De Deckker, et al. (1998). "Stable isotopes, Sr/Ca, and Mg/Ca in biogenic carbonates from Petaluma Marsh, northern California, USA." Geochimica et Cosmochimica Acta 19/20: 3229-3237.

Stable isotope (super(18)O/ super(16)O and super(13)C/ super(12)C) and minor-element compositions (Sr/Ca and Mg/Ca ratios) of ostracodes and gastropods separated from marsh sediments from San Francisco Bay, Northern California, were used to reconstruct paleoenvironmental changes in Petaluma Marsh over the past 700 yr. The value of delta super(18)O in the marsh carbonates reflects changes in freshwater inflow, evaporation, and temperature. Mg/Ca and Sr/Ca in ostracode calcite reflect changes in both freshwater inflow and temperature, although primarily reflect temperature changes in the salinity range of about 10-35ppt. Ostracode delta super(18)O values show a gradual increase by 5ppt between 500 yr BP and the present, probably reflecting rising sea level and increased evaporation in the marsh. Superimposed on this trend are higher frequency Mg/Ca and delta super(18)O variations (3-4ppt), probably reflecting changes in freshwater inflow and evaporation. A period of low Mg/Ca occurred between about 100-300 cal yr BP, suggesting wetter and cooler conditions during the Little Ice Age. Higher Mg/Ca ratios occurred 600-700 cal yr BP, indicating drier and warmer conditions during the end of the Medieval Warm Period. Both ostracode and gastropod delta super(13)C values decrease up-core, reflecting decomposition of marsh vegetation, which changes from C sub(4) (delta super(13)C similar to -12ppt) to CAM (delta super(13)C = -26ppt)-type vegetation over time.

Ingram, B. L., J. C. Ingle, et al. (1996). "A 2000 yr record of Sacramento-San Joaquin River inflow to San Francisco Bay estuary, California." Geology 24(4): 331-334.

Oxygen and carbon isotopic measurements of fossil bivalves (Macoma nasuta) contained in estuarine sediment are used to reconstruct a late Holocene record of salinity and stream flow in San Francisco Bay. Discharge into the bay is a particularly good indicator of paleoclimate in California because the bay's influent streams drain 40% of the state. The isotopic record suggests that between about 1670

and 1900 calendar years (yr cal) B.P. inflow to the bay was substantially greater than the estimated prediversion inflow of 1100 m super(3)/s. An unconformity representing a 900 yr hiatus is present in the core between 1670 and 750 yr cal B.P., possibly caused by a major hydrological event. Over the past 750 yr, stream flow to San Francisco Bay has varied with a period of 200 yr; alternate wet and dry (drought) intervals typically have lasted 40 to 160 yr.

Ingram, B. L., J. C. Ingle, et al. (1996). "Stable isotope record of Late Holocene salinity and river discharge in San Francisco Bay California." Earth and Planetary Science Letters 141(1-4): 237-247.

Oxygen and carbon isotopic measurements of fossil mollusks from San Francisco Bay are used to derive a record of paleosalinity and paleostreamflow for the past 5,900 years. The delta super(18)O and delta super(13)C values of river water (-12ppt and -9ppt) are markedly different than seawater (0ppt and 1ppt), and vary systematically as a function of salinity in the estuary. The data show that the annually averaged salinity in the south-central part of the Bay was very close to the modern 'diversion-corrected' value of 26.8ppt over the past 2,700 years, and 4ppt lower than modern between 3,800 and 5,100 yr B.P. Based on those salinities, the average annual river inflow to San Francisco Bay is calculated to have been 1290 m super(3)/s over the past 2,400 years, and 1990 m super(3)/s between 3,800 and 5,100 yr B.P., 1.8 times greater than the modern 'diversion-corrected' value of 1100 m super(3)/s, assuming a constant bay volume. The inferred river discharge record generally corroborates independent paleohydrologic records in California, including tree-ring, treeline and lake level records.

Ingram, B. L. and J. C. Lin (2002). "Geochemical tracers of sediment sources to San Francisco Bay." Geology 30: 575-578.

River inflow and suspended-sediment flux to San Francisco Bay are dominated by the Sacramento and San Joaquin River systems. Suspended sediments collected from rivers within the Sacramento and San Joaquin drainage basins show distinct chemical and Sr isotope signatures, reflecting their distinct bedrock lithologies. Concentrations of Sm, Nd, K, and Rb and Sr-87/Sr-86 ratios in suspended sediments increase from north to south in Sierra Nevada rivers and are significantly higher in the San Joaquin drainage than in the Sacramento drainage. We show that variations in the geochemistry of fine-grained detrital sediments cored beneath the bay can be used to assess the relative contributions of suspended sediment and inflow from these two major drainages in California. For the sampled intervals over the past 1850 yr, the proportion of suspended sediment from the Sacramento drainage relative to the San Joaquin drainage ranged between 5% and 85% (average value of 55%), compared with a modern value of similar to91%. The current predominance of sediment entering San Francisco Bay from the Sacramento drainage may be the result of greater trapping of sediments by reservoirs within the San Joaquin drainage basin. Changes in the relative proportion of sediment from the Sacramento and San Joaquin drainages may reflect changes in the position of the storm track over California.

Ingram, B. L. and D. Sloan (1992). "Strontium isotopic composition of estuarine sediments as paleosalinity-paleoclimate indicator." Science 255(5040): 68-72.

The strontium isotopic composition of biogenic precipitates that occur in estuarine sediments can be used as proxy indicator of paleosalinity and for assessing precipitation and river discharge rates over thousands of years. In the San Francisco Bay estuary, river water with low super(87)Sr/ super(86)Sr ratio (average, 0.7065) and low Sr concentration (0.13 parts per million) mixes with seawater with a higher super(87)Sr/ super(86)Sr ratio (0.7092) and Sr concentration (7.9 parts per million). The predicted mixing relation between salinity and Sr isotopic composition is confirmed by measurements of modern estuarine surface waters. A paleosalinity record obtained from foraminifera for the ancestral San Francisco Bay during oxygen isotope substage 5e of the last interglacial reflects a global rise and fall of sea level, and short time-scale variations related to fluctuations in discharge rates of the Sacramento and San Joaquin rivers.

Ingram, B. L. and P. K. Weber (1999). "Salmon origin in California's Sacramento-San Joaquin River system as determined by otolith strontium isotopic composition." Geology 27: 851-854.

Geochemical methods for distinguishing salmon of different runs would improve management practices designed to mitigate for declines in salmon populations in California's Sacramento-San Joaquin river system. Strontium isotopic measurements show a strong relationship between the super(87)Sr/ super(86)Sr ratio in hatchery water and the super(87)Sr/ super(86)Sr ratio in the otoliths (aragonitic ear bones) of juvenile chinook salmon (Oncorhynchus tshawytscha) raised in those waters. As a result of differences in basin geology from north to south along the western slope of the Sierra Nevada, important salmon spawning rivers within the Sacramento-San Joaquin river system have distinct super(87)Sr/ super(86)Sr ratios. Of the 10 rivers in this study, those in the Sacramento River drainage have lower super(87)Sr/ super(86)Sr ratios (0.7039-0.7063) than those in the San Joaquin River basin (0.7068-0.7092), with the exception of the American River, which has the highest super(87)Sr/ super(86)Sr ratios in this study (average 0.7100). The combination of distinct river super(87)Sr/ super(86)Sr ratios and the relationship between water and otolith Sr isotope ratios indicates that this geochemical method can be used to identity the origin (and potentially the migration history) of juvenile, out-migrating salmon in the Sacramento-San Joaquin system.

Ingram, C., C. Alexander, and R. Luster (2010). Integrated water operations and ecosystem decision support modelling: The Ecological Flows Tool (EFT). 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

It’s challenging to integrate multi-species and multi-habitat needs when evaluating water operation scenarios. The Ecological Flows Tool (EFT) is a decision support tool emphasizing clear communication of trade-offs for key ecosystem targets associated with alternative conveyance, water operations, and climate change. We take a bottom-up, process-based view of how flow and related aquatic habitat variables (e.g., salinity, temperature, turbidity) are tied to a variety of ecosystem functions for representative sets of focal species and habitats (Chinook salmon, steelhead, green sturgeon, Delta smelt, splittail, tidal wetlands, invasive species deterrence, bank swallows, Fremont cottonwoods). By leveraging many of the same planning models used in existing socioeconomic evaluations (e.g., Calsim, DSM2) EFT provides an “eco plug-in” to the water management studies based on use of these tools. EFT is being used in the BDCP analysis. We present example results from applying EFT to the mainstem Sacramento River, exploring the ecological effects of various water and channel management options on five of the above-listed focal species (results onwww.dfg.ca.gov/ERP/signature_sacriverecoflows.asp). Currently, we are extending EFT to the Delta, expanding existing modules for Chinook and steelhead, and adding components for Delta smelt, splittail, tidal wetlands and invasive species deterrence. In the above applications we’ve found that it’s difficult to simultaneously meet all focal species’ objectives in a single year, but this is not necessarily a problem for some species (e.g. Fremont cottonwood). We have developed a number of approaches to communicate trade-offs across regions and species to both managers and scientists, and catalyze definition of state-dependent management practices that promote the development of needed flexibility in the water management system.

Interagency Ecological Program Estuarine Ecology Team (EET) (1995). Working conceptual model for the food web of the San Francisco Bay/Delta Estuary. Sacramento CA, Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 42.

Interagency Ecological Program Estuarine Ecology Team (EET) (1997). An assessment of the likely mechanisms underlying the "Fish-X2" relationships. Sacramento CA, Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 52.

Isola, C. R., M.A. Colwell, O.W. Taft, and R.J. Safran (2000). "Interspecific differences in habitat use of shorebirds and waterfowl foraging in managed wetlands of California's San Joaquin Valley." Waterbirds 23(2): 196-203.

A common wetland management objective is to provide habitat for a diverse assemblage of species, which requires data on interspecific differences in habitat use. Consequently, we studied habitat use by ten waterbird taxa (four dabbling ducks

and six shorebirds) foraging in managed, seasonal wetlands in the northern San Joaquin Valley, California during late winter and early spring of 1994 and 1995. A MANOVA analysis detected strong interspecific differences in habitat use, with water depth explaining 86% of differences among taxa in a discriminant function analysis. ANOVA identified four groups based on similarities in use of water depth: 1) small shorebirds (<5 cm); 2) large shorebirds (5-11 cm); 3) teal (10-15 cm); and large dabbling ducks (>20 cm). Among these groups, variation in water depth at foraging locations increased with size, suggesting that water depth constrained foraging by shorebirds and teal more than larger waterfowl. In California's Central Valley, where large numbers of shorebirds and waterfowl winter, our findings suggest that managers can provide habitat for shorebirds and waterfowl by reducing the average depth to which habitats are flooded, especially during winter when deep-water habitat is abundant. Within a wetland complex or an individual wetland, this prescription will yield greatest diversity of water depth, and, hence, bird use in wetlands characterized by variable bottom topography.

Israel, J., E. Ringelman, and B. May (2010). Conservation genetics of longfin smelt. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The demographic independence of the longfin smelt (Spirinchus thaleichthys) population inhabiting the San Francisco Bay-Delta is unknown, yet it may be geographically isolated from populations occurring further north along the Pacific Coast. Longfin smelt are an anadromous fish inhabiting estuarine and nearshore marine waters along the western Pacific coast and there exists potential for them to migrate between coastal populations. Genetic information can provide insight into the gene flow between fish from different locations, and the spatial and temporal scales at which longfin smelt collections are differentiated is a critical uncertainty that influences how the species is managed. We developed seventeen microsatellite DNA loci to assess genetic diversity within and among longfin samples from the SF Bay-Delta and Lake Washington, WA. In a preliminary screen of these collections, 5 to 16 alleles per locus were detected, the expected heterozygosity ranged from 0.33-0.93, and moderate levels of differentiation were found. Results from broader temporal samples will be discussed in this presentation to determine the population structure of longfin smelt, and an update about sample collection for other Pacific Northwest locations will be given. The diversity observed in these collections suggests management of longfin smelt may increase sustainability of the population by focusing on segments of the species scaled relevant to natal estuaries along the west coast.

Israel, J., M. Thomas, R. Corwin, A. Hearn, R. Chase, and A.P. Klimley (2010). Implications of seasonal migration impediments on green sturgeon on the Sacramento River. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Telemetry studies provide essential information for evaluating the effects of water operations and delivery facilities on the behavior of fishes. Between 2008 and 2010, at least 46 green sturgeon (Acipenser medirostris) were implanted with acoustic tags by UCD, USBR, and DWR while an additional 15 previously tagged fish entered the upper Sacramento River providing movement and habitat utilization information to assess operational impacts of the Red Bluff Diversion Dam (RBDD) and Delta Cross Channel (DCC) on green sturgeon movements. Green sturgeon in the Sacramento River are the only known spawning population in the threatened Southern Distinct Population Segment and the impact of these facilities on habitat availability and flow volume and direction are hypothesized to influence green sturgeon. We examined the timing of RBDD and DCC gate opening and closure and movements of adult green sturgeon around these facilities to assess the potential for delay or blockage of green sturgeon passage between the San Francisco Bay-Delta and upriver habitats. Operational changes to close RBDD gates later in the spring appear to have provided greater opportunity for fish to reach spawning habitats with optimal egg and larval incubation temperatures later in the spawning season. Adult green sturgeon used the DCC and entered the interior delta before emigrating back towards the west delta and Bay. We evaluated adult green sturgeon movement with hourly and daily flow volume and change in volume to consider potential mechanisms causing outmigration behavior among spring and fall migrants. Green sturgeon

emigration appears reactive to changes in flows and additional studies into understanding behaviors associated with flow cues can reduce exposure of post-spawning adults to potential seasonal stressors in the San Francisco Bay-Delta by reducing operations that may mimic migration cues. This study was funded by the U.S Bureau of Reclamation and utilized the receiver array and database maintained by the California Fish Tracking Consortium.

Israel, J. (2010). Population genetics of longfin smelt. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Israel, J. A. and B. May (2010). "Characterization and evaluation of polymorphic microsatellite markers in the anadromous fish Spirinchus thaleichthys." Conservation Genetics Resources 2(1): 227-230.

We describe seventeen microsatellite loci isolated from longfin smelt, Spirinchus thaleichthys, which is an anadromous fish inhabiting estuarine and nearshore marine waters along the western Pacific coast. Five to 16 alleles per locus were detected, the expected heterozygosity ranged from 0.33–0.93, and moderate levels of differentiation were found between collections. These polymorphic microsatellites will provide useful tools for studying population genetic structure at ecological scales within wild and propagated populations.

Ivey, G., M. Casazza, B. Dugger, J. Fleskes, and C. Herziger (2010). Comparison of winter movements between greater and lesser sandhill cranes in California. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The objective of our study was to compare winter movement patterns of sympatric greater and lesser sandhill cranes (Grus canadensis tabida; G. c. canadensis) wintering in the Sacramento-San Joaquin Delta region of California. We marked 31 greaters and 47 lessers with VHF radios and recorded their roosting and feeding locations throughout the wintering periods in 2007/08 and 2008/09. Ten of these lessers were also marked with platform terminal transmitters and tracked via the Argos Satellite System. Compared to lessers, locations of greaters were much more predictable. Greaters showed strong fidelity to wintering sites, moved between discrete wintering areas less frequently. During the second year of our study, 90% of the greaters returned to the study area, compared to 69% of the lessers. Only two greaters (6%) were located in more than one discrete wintering area, compared to 34% of the lessers. Average flight distances from night roost sites to feeding areas were lower for greaters than for lessers and consequently, winter home range sizes were smaller for greaters. These results have application for conservation of wintering cranes at a landscape scale and indicate that habitat protection and mitigation for the state-threatened greater sandhill crane must occur very close to existing use areas to be successful.

Ivey, G., M. Casazza, B. Dugger, J. Fleskes, and C. Herziger (2010). Migration timing, abundance and distribution of sandhill cranes in the Sacramento-San Joaquin Delta of California. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The Sacramento-San Joaquin Delta is an important wintering area for two subspecies of Sandhill crane (Grus canadensis), including the threatened greater sandhill crane (G. c. tabida). Effective crane conservation and management requires an understanding of migration chronology, winter abundance and distribution, subspecies composition, and significance of the Delta landscape,. We conducted surveys during 2007-08 and 2008-09 to document crane migration chronology, winter abundance and distribution. We counted cranes from the ground bi-weekly at roost sites and during the morning foraging periods at several major use areas in the Delta. We also conducted three aerial surveys on randomly-selected transects in 2007-08. Cranes first arrived in the Delta in early September with arrivals peaking in early October and departures peaking in late February. The last cranes departed in mid-March. Our sandhill crane population estimates from roost counts ranged from 6,421 to 27,213, averaging 15,037 during the winter season. Estimates from aerial surveys (conducted in January and February only) ranged from 9,028 to 21,225 and averaged 16,445. Fluctuations in population estimates over time were primarily due to movements of lesser sandhill cranes (G. c. canadensis) in and out of the Delta. We estimated that at least 2,750 of the state-Threatened greater sandhill cranes wintered in the Delta. We combined a variety of survey data and radio-telemetry locations to map crane distribution in the Delta. This information has implications for focusing management and conservation and future mitigation efforts on the most important regions of the Delta as well as timing of management of roost sites and foraging landscapes for greater sandhill cranes.

Jabusch, T., A. Littlejohn, C. Grosso, T. Featherston, M. May, and J. Chilcott (2010). Central Valley Monitoring Directory: Web-based coordination tool. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The Central Valley Monitoring Directory provides access to program and metadata information of current water quality monitoring efforts in the Central Valley watershed. It began as a pilot study in the San Joaquin River in 2006 and was expanded to include the Central Valley basins of the Sacramento River, Tulare Lake, and Delta. The directory is a tool to help improve the coordination and integration of existing monitoring efforts by allowing users to access monitoring information through a modular search form or interactive map. Key features of the web-based directory include: monitoring program information (objectives, duration, funding, contacts) and metadata (sampling sites, frequency, parameters, data availability); a search form for customized searches; an interactive map for spatial searching and viewing of monitoring locations and program information; password-protected domains for program managers to enter and update monitoring information; and the ability to download information into an Excel file. The Monitoring Directory is maintained and was developed by the San Francisco Estuary Institute (SFEI), with funding and participation from the Central Valley Regional Water Quality Control Board’s Surface Water Ambient Monitoring Program (SWAMP) and the U.S. Environmental Protection Agency (USEPA). The directory is a good example of using USEPA seed money to create enough initial momentum so that additional SWAMP funding could continue to expand the tool. Useful future enhancements include: adding the functionality to upload monitoring results, developing queries for users to search information for a specified time frame, expanding the directory to the entire State, and exchanging data with other information management systems, such as the California Integrated Water Quality System (CIWQS) and the California Environmental Data Exchange Network (CEDEN). These feature enhancements would continue to improve the usefulness of the directory and its ability to provide a more robust information management system for the Central Valley watershed and Bay-Delta.

Jackson, Z. J., and J.P. Van Eenennaam (2013). 2012 San Joaquin River Sturgeon Spawning Survey, Final Annual Report, Stockton Fish and Wildlife Office, Anadromous Fish Restoration Program, U.S. Fish and Wildlife Service, Lodi, CA: 34.

Several researchers have suggested that sturgeon (genus Acipenser) may spawn occasionally in the San Joaquin River during high-water years. Initial documentation of white sturgeon Acipenser transmontanus spawing in the San Joaquin River system occurred in 2011 near Grayson, CA (river kilometer 142, rkm, measuring from its confluence with the Sacramento River). However, whether sturgeon spawn in the San Joaquin River in normal and drier water year types remained unknown. Artificial substrate samplers (i.e. egg mats) were deployed at four sites within a 24-km. reach of the San Joaquin River from Sturgeon Bend (rkm 119) to Grayson Road Bridge (rkm 143) from 16 February to 1 June 2012. During the sample period, 65 white sturgeon eggs were collected among four sites, 45 of which were viable and between develomental states 4 and 28. Based upon capture location, date of capture, water temperature, state of development, and the assumption that a female takes 12-20 hours to release all of her eggs, the eggs most likely represent at least six different females that spawned between 20 March and14 May 2012. The results of this survey confirm that white sturgeon do spawn in the San Joaquin River in both wet- and dry-year conditions and may be an important sources of production for the white sturgeon population in the Sacramento-San Joaquin river system.

Jacobson, T., J.E. Cloern, K. Hieb, B. Sansó, E. Di Lorenzo, M. Stacey, J. Largier, W. Meiring, W. Peterson, and T. Powell (2010). Biological communities in San Francisco Bay track a north pacific climate shift. 6th Biennial Bay-Delta Science

Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Oceanic populations are known to fluctuate in synchrony with large-scale climate patterns, but similar evidence has been lacking for estuaries because of shorter observational records; the dominant driver of estuarine ecosystem variability is often assumed to be river flow. In the San Francisco Bay, fish and invertebrates have been sampled systematically since 1980, and that data series shows large and unexplained changes in populations. Our analysis shows that several demersal populations of fish, crabs, and shrimp covary with two basin-scale modes of North Pacific climate, namely the Pacific Decadal Oscillation (PDO) and North Pacific Gyre Oscillation (NPGO). We present models that show these two modes account for large proportions of variance in these species, even in the presence of local outflow measurements. These findings demonstrate that forecasts of estuarine response to climate change must take into consideration how altered patterns influence coastal oceanography as well as watershed hydrology.

Jaffe, B. E., D. Finlayson, and A. Foxgrover (2010). Will restoration cause loss of mudflats in south San Francisco Bay? 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
A key question in salt pond restoration in South San Francisco Bay is whether sediment sinks created by opening ponds will result in the loss of mudflats. If sediment supply is insufficient, existing mudflats will erode. A decrease in habitat area and altered inundation regime may result in changes in food webs on the mudflats that could reduce their value for migratory birds. The likelihood of salt pond restoration causing mudflat erosion is being evaluated based on long-term and seasonal mudflat changes. A series of bathymetric surveys collected from 1858 to 2005 reveal long-term changes in mudflat area in both space and time that can be used to better understand the pre-restoration system. For example, the mudflat south of the Dumbarton Bridge on the west side of the Bay adjacent to the Ravenswood restoration project narrowed approximately 200 meters from 1858 to 1931. Since then this mudflat has accumulated sediment and is now wider than it was in 1858. At this same site, pre-restoration seasonal bathymetric surveys were collected from 2008 to 2010 using a state-of-the-art interferometric sidescan sonar for swath mapping in extremely shallow water. These high-resolution surveys provide a pre-restoration baseline and indicate that, on average, there is little seasonal change on mudflats adjacent to the Ravenswood ponds. Continued surveying is planned to document changes that occur during restoration. The causes of the spatial and temporal variability in historical muflat area offshore of the Ravenswood ponds are not fully understood, but appear related to sediment redistribution from north to south in the bay and sediment available to deposit on the flats. Improved understanding of sediment input and redistribution within the Bay are needed and will aid in separating restoration effects from more regional effects and help in managing restoration of South San Francisco Bay salt ponds.

Jaffe, B. E., R. E. Smith, et al. (2007). "Anthropogenic influence on sedimentation and intertidal mudflat change in San Pablo Bay, California: 1856-1983." Estuarine, Coastal and Shelf Science 73(1-2): 175-187.
Analysis of a series of historical bathymetric surveys has revealed large changes in morphology and sedimentation from 1856 to 1983 in San Pablo Bay, California. In 1856, the morphology of the bay was complex, with a broad main channel, a major side channel connecting to the Petaluma River, and an ebb-tidal delta crossing shallow parts of the bay. In 1983, its morphology was simpler because all channels except the main channel had filled with sediment and erosion had planed the shallows creating a uniform gently sloping surface. The timing and patterns of geomorphic change and deposition and erosion of sediment were influenced by human activities that altered sediment delivery from rivers. From 1856 to 1887, high sediment delivery (14.1x10 super(6)m super(3)/yr) to San Francisco Bay during the hydraulic gold-mining period in the Sierra Nevada resulted in net deposition of 259+/-14x10 super(6)m super(3) in San Pablo Bay. This rapid deposition filled channels and increased intertidal mudflat area by 60% (37.4+/-3.4 to 60.6+/-6.2km super(2)). From 1951 to 1983, 23+/-3x10 super(6)m super(3) of sediment was eroded from San Pablo Bay as sediment delivery from the Sacramento and San Joaquin Rivers decreased to 2.8x10 super(6)m super(3)/yr because of damming of rivers, riverbank

protection, and altered land use. Intertidal mudflat area in 1983 was 31.8+/-3.9km super(2), similar to that in 1856. Intertidal mudflat distribution in 1983, however, was fairly uniform whereas most of the intertidal mudflats were in the western part of San Pablo Bay in 1856. Sediment delivery, through its affect on shallow parts of the bay, was determined to be a primary control on intertidal mudflat area. San Pablo Bay has been greatly affected by human activities and will likely continue to erode in the near term in response to a diminished sediment delivery from rivers.

Jaffe, B. E., R. E. Smith, et al. (1998). Sedimentation and bathymetric change in San Pablo Bay: 1856-1983. Sacramento CA, U.S. Geological Survey Open File Report 98-759.

Jager, H. I., H. E. Cardwell, et al. (1997). "Modelling the linkages between flow management and salmon recruitment in rivers." Ecological Modelling 103(2-3): 171-191.
We developed a simulation model to predict instream flow effects on smolt production for fall chinook salmon (Oncorhynchus tshawytscha) in regulated rivers. The principal purpose of this model is to serve as a management tool to evaluate effects on salmon of instream releases from upstream reservoirs. The dramatic decline in chinook salmon in California rivers suggests a need for such a tool. We developed an individual-based and spatially explicit model to simulate the influences of riverine habitat on each lifestage leading to successful outmigration of chinook salmon. Model predictions of development, growth and survival showed good agreement with four years of field data collected on the Tuolumne River, California. Our analysis of parameter sensitivities identified flow-related redd mortality and temperature-related juvenile mortality as limitations on smolt production.

Jager, H. I. and K. A. Rose (2003). "Designing Optimal Flow Patterns for Fall Chinook Salmon in a Central Valley, California, River." North American Journal of Fisheries Management 23(1): 1-21.
Widespread declines in stocks of Pacific salmon in the genus Oncorhynchus highlight the need for research to find new and effective management strategies for recovery. Two recovery objectives are (1) to ensure that recruitment is adequate to rebuild self-sustaining populations and (2) to maintain phenotypic diversity. This study seeks to understand how seasonal flow patterns in a flow- regulated California river might be managed to attain each of these recovery objectives, specifically for the fall and late-fall runs of chinook salmon O. tshawytscha. We ask two questions: (1) Does the optimal pattern of seasonal flows change as the amount of water available is constrained by droughts or diversions of flows? and (2) How do optimal flow regimes designed for the two conservation objectives differ? We coupled simulated annealing with a recruitment model to find flow regimes that maximize either the number of smolt out-migrant 'recruits' (MR) or the variation in spawning times among recruits (MV). Optimal flow regimes identified for both the MR and MV objectives changed as we increased the annual quantity of water available, allocating higher flows during the spring and fall seasons. Flow regimes that optimized the MR and MV objectives were different. For example, the MV flow regime with unlimited annual flow provided a pulse of high flow 2 weeks before the peak spawning date of the minority late-fall run. Simulated recruits produced by MV flow regimes were fewer in number: and had parents that spawned later and over a wider range of dates: than recruits produced by MR flow regimes. Although these results have not been verified by empirical studies, they demonstrate the potential for managing species with special conservation status by combining state-of-the-art numerical optimization methods with mechanistic ecological models.

Jarman, W. M., G.W. Johnson, C.E. Bacon, J.A. Davis, R.W. Risebrough, and R. Ramer (1997). "Levels and patterns of polychlorinated biphenyls in water collected from the San Francisco Bay and Estuary, 1993-95." Fresenius' Journal of Analytical Chemistry 359(3): 254-260.
Levels of polychlorinated biphenyls (PCBs) were measured in water (particulate and dissolved fractions) from various locations in the San Francisco Estuary over the years 1993-1995 during six cruises. Geometric mean levels of ΣPCBs (sum of 58 congeners) in the combined dissolved and particulate fractions for the six cruises ranged from 340 ng/L to 1600 ng/L. Comparing this data to previous data

from 1975 and 1980 does not reveal any significant temporal trends. The partitioning of PCBs into the dissolved/particulate fraction were correlated with total suspended solids. Using the novel chemometric technique of polytopic vector analysis (PVA) on the data from cruise 8 (April 1995), five separate PCB congener fingerprints were identified in the data. Fingerprint 1 (or end-member 1) represents a slightly degraded source of Aroclor* 1260 in the northern part of the South Bay; the end-member (EM) 2 fingerprint is related to a predominantly Aroclor® 1260 source that has been moderately-severely degraded present in the highest proportions in the Pacific Ocean sample; EM-3 is interpreted as a slightly degraded Aroclor® 1242:1254:1260 mixture in southern San Pablo Bay: end-member 4 is interpreted as a moderately degraded source of multiple Aroclors® and is present in the river samples; EM-5 is interpreted as a slightly degraded Aroclor® 1254/1260 mixture present in northern San Pablo Bay and the South Bay.

Jassby, A. and E. E. Van Nieuwenhuyse (2005). "Low dissolved oxygen in an estuarine channel (San Joaquin River, California): mechanisms and models based on long-term time series." San Francisco Estuary and Watershed Science 3(2): [np].
The Stockton Deep Water Ship Channel, a stretch of the tidal San Joaquin River, is frequently subject to low dissolved oxygen conditions and annually violates regional water quality objectives. Underlying mechanisms are examined here using the long-term water quality data, and the efficacy of possible solutions using time-series regression models. Hypoxia is most common during June-September, immediately downstream of where the river enters the Ship Channel. At the annual scale, ammonium loading from the Regional Wastewater Control Facility has the largest identifiable effect on year-to-year variability. The longer-term upward trend in ammonium loads, which have been increasing over 10% per year, also corresponds to a longer-term downward trend in dissolved oxygen during summer. At the monthly scale, river flow, loading of wastewater ammonium and river phytoplankton, Ship Channel temperature, and Ship Channel phytoplankton are all significant in determining hypoxia. Over the recent historical range (1983-2003), wastewater ammonium and river phytoplankton have played a similar role in the monthly variability of the dissolved oxygen deficit, but river discharge has the strongest effect. Model scenarios imply that control of either river phytoplankton or wastewater ammonium load alone would be insufficient to eliminate hypoxia. Both must be strongly reduced, or reduction of one must be combined with increases in net discharge to the Ship Channel. Model scenarios imply that preventing discharge down Old River with a barrier markedly reduces hypoxia in the Ship Channel. With the Old River barrier in place, unimpaired or full natural flow at Vernalis would have led to about the same frequency of hypoxia that has occurred with actual flows since the early 1980s.

Jassby, A. D., J. E. Cloern and T.M. Powell (1993). "Organic carbon sources and sinks in San Francisco Bay - variability induced by river flow." Marine Ecology Progress Series 95(1-2): 39-54.
Sources and sinks of organic carbon for San Francisco Bay (California, USA) were estimated for 1980. Sources for the southern reach were dominated by phytoplankton and benthic microalgal production. River loading of organic matter was an additional important factor in the northern reach. Tidal marsh export and point sources played a secondary role. Autochthonous production in San Francisco Bay appears to be less than the mean for temperate-zone estuaries, primarily because turbidity limits microalgal production and the development of seagrass beds. Exchange between the Bay and Pacific Ocean plays an unknown but potentially important role in the organic carbon balance. Interannual variability in the organic carbon supply was assessed for Suisun Bay, a northern reach subembayment that provides habitat for important fish species (delta smelt Hypomesus transpacificus and larval striped bass Morone saxatilus). The total supply fluctuated by an order of magnitude; depending on the year, either autochthonous sources (phytoplankton production) or allochthonous sources (riverine loading) could be dominant. The primary cause of the year-to year change was variability of freshwater inflows from the Sacramento and San Joaquin rivers, and its magnitude was much larger than long-term changes arising from marsh destruction and point source decreases. Although interannual variability of the total organic carbon supply could not be assessed for the southern reach, year-to-year changes in phytoplankton production

were much smaller than in Suisun Bay, reflecting a relative lack of river influence.

Jassby, A. D., and T.M. Powell (1994). "Hydrodynamic influences on interannual chlorophyll variability in an estuary: Upper San Francisco Bay-Delta." Estuarine, Coastal and Shelf Science 39(6): 595-618.
Diversion of estuarine water for human use, in conjunction with river inflow, is the main underlying cause of interannual chlorophyll variability in the landward portion of the San Francisco Bay-Delta estuary, i.e. Suisun Bay and the Sacramento-San Joaquin Delta. The principal feature of year-to-year change is high chlorophyll variability within the specific conductance range of 2-10 mS cm−1 (salinity 1-6), the approximate boundaries of an estuarine turbidity maximum (ETM). This variability stems from two separate hydrodynamic forces: (1) the strength of flow into the ETM, which affects primary productivity, losses to benthic macroinvertebrates, washout of phytoplankton cells, and chlorophyll loading; and (2) export of water from the estuary for human use, which independently affects the loading of chlorophyll from upstream sources into the ETM. In addition to the evidence for (1) presented in previous, largely descriptive studies, the simultaneous existence of both pathways is supported here by statistical models and material budgets. The source of phytoplankton organic matter from upstream was investigated further. Estimates were made for primary productivity levels in the Delta. These estimates are consistent with a mass balance for chlorophyll that suggests the Delta usually augments the flow of phytoplankton biomass from the rivers. If water were diverted from upstream of the Delta, rather than from within the Delta, the mass balance implies that both chlorophyll outflow from the Delta into the Bay, as well as primary productivity within the Delta, would increase. The primary productivity estimates also indicate that, on average, most of the phytoplankton emerging from the Delta is actually produced within the Delta, not upstream in the rivers; furthermore, most of the Delta primary productivity is respired or consumed within the Delta. A second, smaller mode of variability is as a result of phytoplankton blooms in the San Joaquin River, which were quite large and variable prior to 1978 but have been relatively small since that time. The underlying processes have not been identified in detail, but are suspected to be hydrodynamic in nature.

Jassby, A. D., W.J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel, and T.J. Vendlinski (1995). "Isohaline position as a habitat indicator for estuarine populations." Ecological Applications: a publication of the Ecological Society of America 5: 272-289.
Populations of native and introduced aquatic organisms in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary ("Bay/Delta") have undergone significant declines over the past two decades. Decreased river inflow due to drought and increased freshwater diversion have contributed to the decline of at least some populations. Effective management of the estuary's biological resources requires a sensitive indicator of the response to freshwater inflow that has ecological significance, can be measured accurately and easily, and could be used as a "policy" variable to set standards for managing freshwater inflow. Positioning of the 2ppt (grams of salt per kilogram of seawater) bottom salinity value along the axis of the estuary was examined for this purpose. The 2ppt bottom salinity position (denoted by X sub(2)) has simple and significant statistical relationships with annual measures of many estuarine resources, including the supply of phytoplankton and phytoplankton-derived detritus from local production and river loading; benthic macroinvertebrates (molluscs); mysids and shrimp; larval fish survival; and the abundance of planktivorous, piscivorous, and bottom-foraging fish. The actual mechanisms are understood for only a few of these populations. X sub(2) also satisfies other recognized requirements for a habitat indicator and probably can be measured with greater accuracy and precision than alternative habitat indicators such as net freshwater inflow into the estuary. The 2ppt value may not have special ecological significance for other estuaries (in the Bay/Delta, it marks the locations of an estuarine turbidity maximum and peaks in the abundance of several estuarine organisms), but the concept of using near-bottom isohaline position as a habitat indicator should be widely applicable. Although X sub(2) is a sensitive index of the estuarine community's response to net freshwater inflow, other hydraulic features of the estuary also determine population abundances and resource

levels. In particular, diversion of water for export from or consumption within the estuary can have a direct effect on population abundance independent of its effect on X sub(2). The need to consider diversion, in addition to X sub(2), for managing certain estuarine resources is illustrated using striped bass survival as an example. The striped bass survival data were also used to illustrate a related important point: incorporating additional explanatory variables may decrease the prediction error for a population or process, but it can increase the uncertainty in parameter estimates and management strategies based on these estimates. Even in cases where the uncertainty is currently too large to guide management decisions, an uncertainty analysis can identify the most practical direction for future data acquisition.

Jassby, A. D., J. R. Koseff and S. G. Monismith. (1996). Processes underlying phytoplankton variability in San Francisco Bay. San Francisco Bay: The Ecosystem. J. T. Hollibaugh. San Francisco, CA, Pacific Division of the American Association for the Advancement of Science
AAAS: 325-350.

Jassby, A. D., B. E. Cole, and J. E. Cloern (1997). "The design of sampling transects for characterizing water quality in estuaries." Estuarine, Coastal and Shelf Science 45(3): 285-302.
The high spatial variability of estuaries poses a challenge for characterizing estuarine water quality. This problem was examined by conducting monthly high-resolution transects for several water quality variables (chlorophyll a, suspended particulate matter and salinity) in San Francisco Bay (California, U.S.A.). Using these data, six different ways of choosing station locations along a transect, in order to estimate mean conditions, were compared. In addition, 11 approaches to estimating the variance of the transect mean when stations are equally spaced were compared, and the relationship between variance of the estimated transect mean and number of stations was determined. The results provide guidelines for sampling along the axis of an estuary: (1) choose as many equally-spaced stations as practical; (2) estimate the variance of the meanyby var (y)=(1/10n2)Σnj=2(yj−yj−1)2, where y1, . . .,yn are the measurements at the n stations; and (3) attain the desired precision by adjusting the number of stations according to var(y)α1/n2. The inverse power of 2 in the last step is a consequence of the underlying spatial correlation structure in San Francisco Bay; more studies of spatial structure at other estuaries are needed to determine the generality of this relationship.

Jassby, A. D. (1998). "Interannual variability at three inland water sites: implications for sentinel ecosystems." Ecological Applications 8: 277-287.
In the sentinel-site approach to monitoring ecological resources, relatively small numbers of locations are chosen for intensive study, each location being selected to represent a certain, preferably large, class of ecosystems. This paper examines long-term studies at three inland aquatic ecosystems in California that, although never intended as sentinel sites, nevertheless illustrate the challenges posed by sentinel-site networks. The main mechanisms of interannual variability in primary productivity or producers are described for Castle Lake, Lake Tahoe, and northern San Francisco Bay. The external forces behind the variability include climate (in the form of both snowfall and total precipitation), fishing intensity, anthropogenic nitrogen emissions, spring weather systems, intrinsic population cycles, forest fires, water diversions, and invasions of exotics. Each mechanism is associated with certain critical ecosystem features (such as hydraulic residence time) that condition a responsiveness to one or a combination of these external forces (such as precipitation); these critical features are identified for each mechanism. Three demanding conditions must be fulfilled in order for a sentinel site to function with regard to a given stressor: (1) some subset of the network must encounter the stressor; (2) at least some sites in the subset must have the critical features that cause responsiveness to that stressor; and (3) the background variability at those sites must not disguise the response to the stressor of interest. In practice, reliable extrapolation from sentinel-site networks to regional trends appears to be beyond our ecological understanding at the present time.

Jassby, A. D. (1999). Uncovering mechanisms of interannual variability from short ecological time series. Integrated assessment of ecosystem health. K. M. Scow, G. E. Fogg, D. E. Hinton and M. L. Johnson. Boca Raton, Lewis: 285-306.

Jassby, A. D., and J. E. Cloern. (2000). "Organic matter sources and rehabilitation of the Sacramento-San Joaquin Delta (California, USA)." Aquatic Conservation: Marine and Freshwater Ecosystems 10(5): 323-352.

(1)The Sacramento–San Joaquin River Delta, a complex mosaic of tidal freshwater habitats in California, is the focus of a major ecosystem rehabilitation effort because of significant long-term changes in critical ecosystem functions. One of these functions is the production, transport and transformation of organic matter that constitutes the primary food supply, which may be sub-optimal at trophic levels supporting fish recruitment. A long historical data set is used to define the most important organic matter sources, the factors underlying their variability, and the implications of ecosystem rehabilitation actions for these sources. (2)Tributary-borne loading is the largest organic carbon source on an average annual Delta-wide basis; phytoplankton production and agricultural drainage are secondary; wastewater treatment plant discharge, tidal marsh drainage and possibly aquatic macrophyte production are tertiary; and benthic microalgal production, urban run-off and other sources are negligible. (3)Allochthonous dissolved organic carbon must be converted to particulate form—with losses due to hydraulic flushing and to heterotroph growth inefficiency—before it becomes available to the metazoan food web. When these losses are accounted for, phytoplankton production plays a much larger role than is evident from a simple accounting of bulk organic carbon sources, especially in seasons critical for larval development and recruitment success. Phytoplankton-derived organic matter is also an important component of particulate loading to the Delta. (4)The Delta is a net producer of organic matter in critically dry years but, because of water diversion from the Delta, transport of organic matter from the Delta to important, downstream nursery areas in San Francisco Bay is always less than transport into the Delta from upstream sources. (5)Of proposed rehabilitation measures, increased use of floodplains probably offers the biggest increase in organic matter sources. (6) An isolated diversion facility—channelling water from the Sacramento River around the Delta to the water projects—would result in substantial loading increases during winter and autumn, but little change in spring and summer when food availability probably matters most to developing organisms. (7) Flow and fish barriers in the channel could have significant effects, especially on phytoplankton sources and in dry years, by eliminating ‘short-circuits’ in the transport of organic matter to diversion points. (8) Finally, productivity of intentionally flooded islands probably would exceed that of adjacent channels because of lower turbidity and shallower mean depth, although vascular plants rather than phytoplankton could dominate if depths were too shallow.

Jassby, A. D., J. E. Cloern and B. E. Cole. (2002). "Annual primary production: Patterns and mechanisms of change in a nutrient-rich tidal ecosystem." Limnology and Oceanography 47(3): 698-712.

Although nutrient supply often underlies long-term changes in aquatic primary production, other regulatory processes can be important. The Sacramento–San Joaquin River Delta, a complex of tidal waterways forming the landward portion of the San Francisco Estuary, has ample nutrient supplies, enabling us to examine alternate regulatory mechanisms over a 21-yr period. Delta-wide primary productivity was reconstructed from historical water quality data for 1975–1995. Annual primary production averaged 70 g C m22, but it varied by over a factor of five among years. At least four processes contributed to this variability: (1) invasion of the clam Potamocorbula amurensis led to a persistent decrease in phytoplankton biomass (chlorophyll a) after 1986; (2) a long-term decline in total suspended solids—probably at least partly because of upstream dam construction—increased water transparency and phytoplankton growth rate; (3) river inflow, reflecting climate variability, affected biomass through fluctuations in flushing and growth rates through fluctuations in total suspended solids; and (4) an additional pathway manifesting as a long-term decline in winter phytoplankton biomass has been identified, but its genesis is uncertain. Overall, the Delta lost 43% in annual primary production during the period. Given the evidence for food limitation of primary consumers, these findings provide a partial explanation for widespread Delta species declines over the past few decades. Turbid nutrient-rich systems such as the Delta may be inherently more variable than other tidal systems because certain compensatory processes are absent. Comparisons among systems, however, can be tenuous because conclusions about the magnitude and mechanisms of variability are dependent on length of data record.

Jassby, A. D., J.E. Cloern, A. Mueller-Solger (2003). "Phytoplankton fuels the food web in Delta waterways." California Agriculture 57: 6.

Jassby, A. D. (2005). "Phytoplankton regulation in a eutrophic tidal river (San Joaquin River, California)." San Francisco Estuary and Watershed Science 3(1): [vp].

As in many U.S. estuaries, the tidal San Joaquin River exhibits elevated organic matter production that interferes with beneficial uses of the river, including fish spawning and migration. High phytoplankton biomass in the tidal river is consequently a focus of management strategies. An unusually long and comprehensive monitoring dataset enabled identification of the determinants of phytoplankton biomass. Phytoplankton carrying capacity may be set by nitrogen or phosphorus during extreme drought years but, in most years, growth rate is light-limited. The size of the annual phytoplankton bloom depends primarily on river discharge during late spring and early summer, which determines the cumulative light exposure in transit downstream. The biomass-discharge relationship has shifted over the years, for reasons as yet unknown. Water diversions from the tidal San Joaquin River also affect residence time during passage downstream and may have resulted in more than a doubling of peak concentration in some years. Dam construction and accompanying changes in storage-and-release patterns from upstream reservoirs have caused a long-term decrease in the frequency of large blooms since the early 1980s, but projected climate change favors a future increase. Only large decreases in nonpoint nutrient sources will limit phytoplankton biomass reliably. Growth rate and concentration could increase if nonpoint source management decreases mineral suspensoid load but does not decrease nutrient load sufficiently. Small changes in water storage and release patterns due to dam operation have a major influence on peak phytoplankton biomass, and offer a near-term approach for management of nuisance algal blooms.

Jassby, A. D. (2008). "Phytoplankton in the upper San Francisco Estuary: Recent biomass trends, their causes and their trophic significance." San Francisco Estuary and Watershed Science 6(1): Issue 1 Article 2.

Several pelagic fish populations in the upper San Francisco Estuary have recently declined to historically low abundances, prompting an interest in the status of their food supply. Previous studies have indicated that the primary food supply for metazoans in the Delta is phytoplankton productivity, and the long-term decrease in phytoplankton over the last few decades may very well play a role in the long-term decline of pelagic fish abundance. Regional phytoplankton biomass trends during 1996–2005, however, are positive in the Delta and neutral in Suisun Bay, the two major sub-regions of the upper estuary. The trend in Delta primary productivity is also positive. Changes in phytoplankton biomass and production during the last decade are therefore unlikely to be the cause of these more recent metazoan declines. The main source of interannual phytoplankton variability in the Delta during 1996–2005, including the upward trend, appears to have been freshwater flow variability and its effect on particle residence time. This conclusion is supported by trend analyses; the concurrence of these time trends at widely-separated stations; empirical models at the annual and monthly time scales; particle residence time estimates; and experience from other estuaries. A significant temperature increase was also noticed, at least partially independent of flow changes, but its net effect on the phytoplankton community is unknown because of differential effects on growth and loss processes. Phytoplankton biomass in Suisun Bay, in contrast to the Delta, did not increase during 1996–2005. Consistent with this observation, Suisun Bay phytoplankton exhibited relatively low responsiveness to flow variability. This behavior differs from earlier chlorophyll-flow relationships reported in the literature. The reason appears to be the invasion of Suisun Bay by a clam—Corbula amurensis—in 1986, which has since maintained the phytoplankton community mostly at low levels by vigorous filter-feeding. In the past, flows into

Suisun Bay generally diluted the higher phytoplankton concentrations within the bay; now they bring in higher phytoplankton concentrations from upstream. The supply of phytoplankton carbon to Suisun Bay has always been dominated by allochthonous sources, at least for mean flow conditions. Now this dominance must be even more pronounced.

Jennings, M. R., and M.K. Saiki (1990). "Establishment of red shiner, Notropis lutrensis, in the San Joaquin Valley, California (USA)." California Fish and Game 76(1): 46-57.
Red shiner, Nolropis lutrensi+ recently introduced into the San)oaquin Valley,
California are spreading lhrou~hout the Valley floor. Densities of shiner were
highest in irrigation canals and drains, and other small, shallow, unstable aquatic
habitats that were slrongly influenced by agricultural and other human-related activities. These habitats were characterized by elevated turbidity, conductivity,
total dissolved solids, total alkalinity, and total hardness. Fish species closely
associated with red shiner were common carp, Cypdnus carplo, threadfin shad, Oorosoma pefenense, mosquitofish, Gambusia affinis, inland nilverside, Menidia beryllina, striped bass, Morane saxatilis, fathead minnow, Pimephalespmmelas, and Sacramento blackfish, Orthodon mi~mIepidofus. All of these species are generally able to tolerate \he harsh conditions present in many streams and rivers on the Valley floor. Limited observations on the life history of red shlner in the Valley
showed them to be similar ta endemic populations in the Mississlppl River basin. Adults (moslly fish in their second growing season) were reproductively active from April to October. Major foods of these fish included filamentous algae and aquatic insect larvae. However, red shiner in irrigation drains, and canals on the Valtey floor. also consumed terrestrial ants (Formicidae). The species is expected to
eventually spread through the entire lower San Joaquin River system.

Johns, C., S.N. Luoma, and V. Elrod (1988). "Selenium accumulation in benthic bivalves and fine sediments of San Francisco Bay, the Sacramento-San Joaquin Delta (USA), and selected tributaries." Estuarine, Coastal and Shelf Science 27(4): 381-396.
Spatial distributions of selenium were determined in fine-grained, oxidized, surface sediments and in two benthic bivalves (Corbicula sp., a suspension-feeding freshwater clam, and Macoma balthica, a deposit-feeding brackish-water clam) within San Francisco Bay, the San Joaquin River and three river systems unlikely to be subject to selenium inputs. Biologically available selenium enters the middle reaches of the San Joaquin River from agricultural runoff. However, selenium concentrations in sediments and Corbicula in the lower San Joaquin, upstream from San Francisco Bay, were not significantly different from concentrations in rivers with no known selenium inputs. Biologically available selenium did not appear to enter the northernmost reach of San Francisco Bay from the San Joaquin River in levels which could measurably influence bioaccumulation by Corbicula. Selenium concentrations in Corbicula were enriched in the northernmost reach of San Francisco Bay compared with the rivers, but several lines of evidence suggested that local inputs (perhaps from urban/industrial waste discharges) were the most important sources. Selenium concentrations in Macoma balthica were also elevated at one station in the northern reach of the Bay and at one station in the extreme South Bay. However, no enrichment was evident at two other stations, suggesting a lack of bay-wide contamination. No significant correlation between selenium and mercury concentrations in Corbicula tissues was observed.

Johnson, C., K. Aceituno, K. Kroll, and N. Denslow (2010). Evaluation of contaminants and endocrine disruption in the Sacramento – San Joaquin Estuary, CA, USA. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The objective of the study is to determine the presence of the endocrine disruption biomarker vitellogenin in the Sacramento splittail (Pogonichthys macrolepidotus), a native fish of the Sacramento/San Joaquin River estuary and determine contaminant profile by deploying semi-permeable membrane devices (SPMD) and Polar Organic Chemical Integrative Samplers (POCIS). There has been increasing concern regarding the role of environmental contaminants in the Sacramento and San Joaquin watershed. It is widely recognized that there are numerous chemicals in the aquatic environment that have adverse affects in aquatic organisms. At least 45 chemicals have been identified as potential endocrine-disrupting contaminants, including industrial, municipal, agricultural contaminants, insecticides, alkylphenoxy compounds, and herbicides. The principal habitat of splittail is the Sacramento-San Joaquin estuary. Sampling of fish took place at Suisun Slough and its tributaries. Blood is collected from the caudal vein and immediately centrifuged to separate blood plasma from red blood cells. The blood plasma is flash frozen and kept frozen until vitellogenin analysis. Water sampling is done via SPMD and POCIS. SPMDs and POCIS are passive sampling devices used to monitor trace levels of organic contaminants. Concentrations of endocrine disrupting chemicals in rivers can change daily or even hourly. SPMDs and POCIS allow us to get true picture of contaminant present in the water that the splittail reside and spawn in. The chemical analysis consisted of a scan of non-polar compounds (pyrethroids, PCB’s, PBDE’s, and nonylphenol). Several organochlorines were detected such as dieldrin, chlordane and DDE, at levels of 58.4 ppb, 23.8 ppb and 61.2 ppb, respectively. PCB’s were also found. Chlorpyrifos was detected at 154 ppb in the River site and between 49.4 ppb and 23.2 ppb in the Suisun slough sites. PCB’s were also detected at levels ranging from 32.3 ppb to 73.4 ppb. Contaminant concentrations are reported from the spmd and will be presented in water concentration. Seventeen blood samples were analyzed on male and female splittail for Vtg. Female Vtg ranged from 0.016 mg/ml to 10.05 mg/ml; whereas Vtg levels in males ranged from 0.017 mg/ml to 52.5 mg/ml.

Johnson, G. W., W. M. Jarman, et al. (2000). "Resolving polychlorinated biphenyl source fingerprints in suspended particulate matter of San Francisco Bay." Environmental Science and Technology 34(4): 552-559.

The presence of PCB contamination in San Francisco Bay has been documented, but the number of sources, their chemical composition, and their geographic/temporal distribution are poorly understood. A self-training pattern recognition technique, polytopic vector analysis is used to determine those parameters from PCBs adsorbed on the particulate fraction of surface waters. Five chemical fingerprints (end-members) were resolved. Four were consistent with published Aroclor patterns. Aroclor 1260 was observed throughout the estuary, in all cruises, with highest proportions observed in Coyote Creek, a tributary of the South Bay. A pattern that matches typical Aroclor 1254 was observed in all cruises but was in generally higher abundance in spring 1995. A second Aroclor 1254 pattern, consistent with an atypical Aroclor 1254 batch described in the literature, was observed in moderate proportions in the three 1996 cruises. Aroclor 1248 was present in significant proportions in only one cruise (cruise 12: July 1996) but was the dominant fingerprint in the Central Bay samples collected at that time. End-member 5 did not match published Aroclor source patterns. Its composition exhibits high proportions of the metabolism-resistant congeners PCB-138 and PCB-153. The source of this pattern is not known, but we hypothesize that it may be due to sewage inputs in the Bay or from atmospheric inputs.

Johnson, H., J. Domagalski, and D. Saleh (2010). Trends in pesticide concentrations in five streams of the California Central Valley, 1993-2005. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The Sacramento and San Joaquin Rivers deliver over 1,000 kilograms of pesticides to the Sacramento-San Joaquin River Delta each year. Over the last two decades, millions of dollars have been spent to reduce pesticide transport from agricultural and urban sources. A quantitative understanding of the efficacy of these efforts is lacking, owing to intermittent monitoring and hydrologic variability that make it difficult to assess the changes in pesticide concentrations. To assess pesticide reduction efforts, we have evaluated trends in pesticide concentrations for five streams in California's Central Valley using a

parametric regression model that accounts for flow variability and seasonal use. Trends were determined for the organophosphate insecticides chlorpyrifos and diazinon and the herbicides atrazine, EPTC, metolachlor, simazine, and trifluralin. Trends were computed for the period 1993 to 2005. The modeled streams include two large rivers: San Joaquin River near Vernalis and Sacramento River near Freeport, one mid-sized river: Merced River near Newman, and two small creeks: Orestimba Creek near Crows Landing and Arcade Creek near Sacramento. Decreasing trends most often were observed for diazinon, and reflect a variety of regulatory pressures on the chemical during the study period. Consistent trends were observed for several herbicides, including upward trends in simazine at urban-influenced sites, and downward trends in atrazine and EPTC at agricultural sites. The model we used to calculate trends also enabled us to reconstruct daily concentrations for each pesticide during each year of the modeling period. These data can be used to estimate the frequency with which a stream exceeds ambient water quality criteria or regulatory endpoints. Several examples will be presented.

Johnson, M., I. Werner, and S.J. Teh (2010). POD Synthesis Report. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Johnston, S. (2010). Fine-scale three-dimensional tracking of fish behavior in central California using acoustic tags. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Micro-acoustic tags have been used to monitor the fine-scale three-dimensional behavior and survival of fish and other aquatic life in the Pacific Northwest and Central California for years. Three-dimensional tracks are obtained at dams, lakes, open rivers, estuaries, and in marine environments. Resolution of three-dimensional positions are sub-meter with some resolutions as fine as 20 cm. In addition to juvenile and adult salmonids, other species tracked include eel, lamprey, sturgeon, shad, crab and shrimp. Salmonid smolts as small as 92 mm have been tagged and tracked with acoustic tags weighing as little as 0.5 g. Today’s acoustic tag technology allows researchers to view fish behavior and passage in real-time. Tags operated at 307 kHz with a user-specified pulse width of 1-5 msec. Recent innovations include the development of smaller tags weighing 0.5 g in air, longer life tags, remote access via smartphone, as well as various data display options. This poster illustrates example fish tracks and what can be learned from behavioral data. Recent Sacramento-San Joaquin River examples will be featured.

Jones, K., J. Anderson, B. Cavallo, J. Merz, J. Setka, and C. Watry (2010). An experimental evaluation of flow and predation effects on the survival of juvenile Chinook salmon. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Non-native predators are thought to significantly reduce through-Delta survival of juvenile salmonids. However, the factors which mediate predation in the Delta are poorly understood. For example, flow, turbidity and predator density are all known to influence predation, yet no experiments have evaluated the relative influence of these factors. An improved understanding of Delta predation is critical to developing and testing effective management actions. For example, predator management is considered a promising strategy for improving salmon production, yet we lack the data necessary to make defensible quantitative assessments. Similarly, the influence of Delta flows (particularly river discharge vs. tidally driven flows) on predation mortality is a critical issue for water project operation planning and for ESA recovery efforts. In order to address these issues, we conducted a Before-After Control-Impact (BACI) experiment to test the effect of flow and predator densities on the survival of hatchery Chinook implanted with Juvenile Salmon Acoustic Telemetry System (JSATS) tags. Our study included two reaches on the North Fork Mokelumne River, including one predator-removal reach (impact) and one non-predator removal reach (control). Fish were released both before and after predator removal treatments for comparisons. Control and impact sites were also used before and after the DCC was opened to test for flow effects on predation. In total, 512 fish were released during the study, consisting of 16 groups of 32 fish. Predator removal was accomplished using electrofishing and took place on the North

Fork adjacent to Dead Horse Island (approximately 1.8 miles downstream of the DCC) and estimation of predator numbers was made via a three-pass electrofishing depletion method. In total, 657 predators were removed during the study period, consisting of 22 species. Acoustic data were retrieved for this study from five acoustic receivers placed along the study reaches between May 13 and June 15, 2010.

Jones, N. L., J. K. Thompson, et al. (2008). "A Note on the Effect of Wind Waves on Vertical Mixing in Franks Tract, Sacramento-San Joaquin Delta, California " San Francisco Estuary and Watershed Science 6(2): Article 4.

A one-dimensional numerical model that simulates the effects of whitecapping waves was used to investigate the importance of whitecapping waves to vertical mixing at a 3-meter-deep site in Franks Tract in the Sacramento-San Joaquin Delta over an 11-day period. Locally-generated waves of mean period approximately 2 s were generated under strong wind conditions; significant wave heights ranged from 0 to 0.3 m. A surface turbulent kinetic energy flux was used to model whitecapping waves during periods when wind speeds > 5 m s-1 (62% of observations). The surface was modeled as a wind stress log-layer for the remaining 38% of the observations. The model results demonstrated that under moderate wind conditions (5-8 m s-1 at 10 m above water level), and hence moderate wave heights, whitecapping waves provided the dominant source of turbulent kinetic energy to only the top 10% of the water column. Under stronger wind (> 8 m s-1), and hence larger wave conditions, whitecapping waves provided the dominant source of turbulent kinetic energy over a larger portion of the water column; however, this region extended to the bottom half of the water column for only 7% of the observation period. The model results indicated that phytoplankton concentrations close to the bed were unlikely to be affected by the whitecapping of waves, and that the formation of concentration boundary layers due to benthic grazing was unlikely to be disrupted by whitecapping waves. Furthermore, vertical mixing of suspended sediment was unlikely to be affected by whitecapping waves under the conditions experienced during the 11-day experiment. Instead, the bed stress provided by tidal currents was the dominant source of turbulent kinetic energy over the bottom half of the water column for the majority of the 11-day period.

Jones, R. (2010). Water Temperature in San Francisco Bay, Water Years 2008 and 2008. IEP Newsletter. 23: 2.

Josselyn, M. N. and J. A. West (1985). "The distribution and temporal dynamics of the estuarine macroalgal community of San Francisco Bay." Hydrobiologia 129: 139-152.

Kadir, T., G. Huang, and F. Chung (2010). Potential impacts of climate change on the upper Feather River Basin hydrology. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

We quantitatively evaluate the hydrologic response of the Upper Feather River Basin to climate change with the physically-based, spatially-distributed PRMS hydrologic models. Starting with the calibrated hydrologic models and historical hydro-climatic dataset, wavelet spectral analysis is performed on historical hydro-climatic time series data which reveals strong seasonal, annual and intra-annual (2-4 years) non-random variability in naturalized streamflow and strong correlations among hydro-climatic variables. Detrending of air temperature forcing data is performed after strong linear trends are identified and estimated at several climate stations. After detrending only the natural variations remains in the historical data, PRMS models forced with this quasi-stationary temperature data are able to produce quasi-stationary hydrologic outputs and the observed strong decreasing trend in April-July fraction of annual flows into Lake Oroville is virtually gone. Temperature-driven sensitivity analysis (+1°C to +4°C) shows that basin-wide snowfall as a form of precipitation will be reduced by -19% to -67% and annual snowmelt will be reduced by -10.8% to -51.9%. While absolute changes in annual streamflow is quite small (less than 2.1%), monthly total runoff is increased by as much as 80% in the winter months and decreased sharply in the summer months by about 60%. Six GCM models with two IPCC CO2 emissions scenarios (A2 and B1) were chosen to represent a range of climate change projections. All simulations based on the GCM scenarios consistently show reduced snowpack storage, declined summer runoff

and increased winter streamflow as air temperature increases. Therefore, the implications for reservoir operation at the watershed outlet (Lake Oroville) is that whether the original operation rule based on historical hydrology can still accommodate a substantial shift in streamflow timing and seasonality and a large reduction in natural snowpack storage.

Karpov, K. A. and G. S. Kwiecien (1988). Conversions between total, fork, and standard lengths
for 41 species in 15 families of fish from California using preserved and fresh specimens. Sacramento, California Department of Fish and Game, Marine Resources Division.

Karpuzcu, E., J. Hanlon, D. Sedlak, and W. Stringfellow (2010). Spatial and temporal variation in the biodegradation of organophosphate pesticides in riparian wetlands in agricultural watersheds. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Organophosphate pesticides rank among the most widely used insecticides in the United States. Runoff from irrigation and precipitation can transport dissolved and particulate-associated pesticides into adjacent water bodies, where they may impact non-target aquatic invertebrates and fish. The organophosphate chlorpyrifos (O,O-diethyl O-3,5,6-trichloro-2 pyridylphosphorothioate) is one of the most intensively used organophosphate insecticides in agriculture. The biodegradation of chlorpyrifos in sediments from agricultural drains and riparian wetlands in San Joaquin Valley, California was investigated. Five agricultural watersheds were selected for inclusion in this study. The sites were chosen based on their diverse levels of riparian function and their inclusion in pesticide monitoring plans and other water quality studies. Stream sediments were collected, transported to the laboratory, and rates of chlorpyrifos loss were measured using a standardized aerobic biodegradation assay. Phosphoesterase enzyme activities were measured and related to observed biodegradation kinetics. First-order biodegradation rates varied between 0.02 and 0.38 day-1. Sites showed temporal and spatial variation in observed biodegradation rates. The watersheds included in this study have similar cropping practices. Other factors, such as pesticide exposure histories, degree of riparian vegetation, and levels of in-stream primary productivity are being investigated as possible factors for predicting difference in biodegradation potential between watersheds. Phosphoesterase enzymes are known to be involved in biodegradation of organophosphate pesticides; however, relative phosphomonoesterase and phosphodiesterase activities were not reliable surrogate measures of relative chlorpyrifos biodegradation rates. The possibility of phosphotriesterase activity being an indicator of the initial biodegradation rate is under investigation. The results of these experiments are part of an effort to understand factors controlling the biodegradation of organophosphate pesticides in riparian wetlands receiving agricultural drainage water.

Kawakami, B., B. Cavallo, and G. Gartrell (2010). Evaluation of potential conflicts between protection of winter-run chinook salmon and delta smelt. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The goals of maintaining adequate in-stream temperatures during the summer for salmon and maintaining sufficient outflow to provide adequate quality and quantity of delta smelt habitat during the fall may result in potential water management conflicts (e.g. being able to maintain sufficient levels of Shasta storage). In order to understand the potential conflicts and allow for improved decision making for setting water management requirements for both species, a side-by-side comparison of the benefits and impacts of summer temperature and fall outflow management on both species is needed. The comparison should quantitatively evaluate the inherent trade-offs and the timing and conditions under which they occur. CALSIM simulations that included implementation of both summer temperature management for salmon and fall outflow management for delta smelt actions were used to represent the implementation of both types of management strategies simultaneously. Delta Simulation Model II simulations were used to determine salinity and salinity effects on delta smelt were evaluated using previously established relationships between salinity and fall distribution patterns. Effects

of temperature management on winter-run salmon were evaluated using the Integrated Object-Oriented Salmon Simulation (IOS) model by Cramer Fish Sciences. Potential conflicts between management actions between delta smelt and winter-run chinook salmon were identified and characterized in tThis research provides an improved basis for decision making on management actions to protect delta smelt and winter-run chinook salmon. This research should inform ongoing efforts to better integrate the actions for both species. It provides a quantitative risk assessment that allows for incremental scaling of water management actions to produce the best balance for providing adequate protection of both species.

Kelley, D. W., Ed. (1966). Ecological studies of the Sacramento-San Joaquin Estuary. Fish Bulletin 133.

The Delta Fish and Wildlife Protection Study was organized in 1961 to investigate the effects of future water development on fish and wildlife resources dependent upon the Sacramento-San Joaquin River estuary, and to recommend measures to protect and enhance these resources. The investigations described in this bulletin were designed to answer a number of specific questions relevant to water development plans and also to start us toward an understanding of the estuary's ecology. The bulletin describes the results of about 2 years of collecting and 1 year of analysis on zooplankton, zoobenthos, and fishes of the middle or bay portion of this estuary and on zooplankton and zoobenthos of the upper portion that is known as the Delta.

Kelley, D. W. (1967). "IDENTIFICATION OF COROPHIUM FROM SACRAMENTO-SAN JOAQUIN DELTA." California Fish and Game 53(4): 295-&.

Kelley, D. W. and J. L. Turner (1966). "FISHERIES PROTECTION AND ENHANCEMENT WITH WATER DEVELOPMENT OF SACRAMENTO - SAN JOAQUIN ESTUARY." Transactions of the American Fisheries Society 95(4S): 78-&.

Kelley, K. M., C.M. Waggoner, N.K. Brar, and J.A. Reyes (2010). Environmental disruption in the thyroid endocrine system of wild fish in San Francisco Bay. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The thyroid endocrine system is essential for normal growth and development in vertebrates, among other critical physiological functions. Therefore, environmental disruption of this endocrine system poses a significant threat either through lethal or sub-lethal effects. In our studies of the San Francisco Bay region, substantial alterations in plasma levels of the two thyroid hormones, thyroxine (T4) and triidothyronine (T3), have been observed in resident fish including shiner surfperch and Pacific staghorn sculpin. Significant reductions in T4 are observed in both species when sampled from contaminated locations such as Oakland Harbor or nearby San Leandro Bay, as compared with locations representing relatively lower impacts (e.g., Bodega Bay, Redwood City, Catalina Island). T3 levels also exhibit significant differences relating to sampling location. Measurements of tissue organic contaminant concentrations within the same fish indicate that polychlorinated biphenyls (PCBs) are particularly prominent in exhibiting significant correlations with thyroid endocrine parameters. T4 concentrations are inversely correlated with several PCB congeners (most all non-coplanar, lower-chlorinated forms), while in contrast T3 and T3/T4 ratio are positively correlated. The increased T3/T4 ratios indicate possible PCB effects in altering the peripheral 5’-deiodinase system (which converts T4 into the more active T3). However, in follow-up experiments, it is clear that thyroid gland function is also compromised, since treatment of PCB-contaminated fish with pituitary thyroid-stimulating hormone (TSH) fails to exert its normal action of activating T4 production. In conclusion, this work demonstrates that wild fish residing in contaminated San Francisco Bay locations exhibit significant disruptions in their critically important thyroid endocrine system. The work also demonstrates that measurement of thyroid hormones is effective in elucidating location- and contaminant-related environmental impairment. (Support by SFEI-RMP for Water Quality in SF Bay; NOAA-USC Sea Grant Program/California Coastal Conservancy; Pacific Coast Environmental Conservancy).

Kendall, C., S. Silva, M. Young, T. Kraus, M. Guerin, A. Parker, and C. Foe (2010). Causes of seasonal and spatial variation in water chemistry in the Sacramento River, Delta, and eastern San Francisco Bay and their effects on chlorophyll levels. 6th Biennial Bay-Delta Science Conference, Workshop presentation at the Sacramento Convention Center, Sacramento, California.
High concentrations of NH4 have been hypothesized to suppress phytoplankton blooms, contributing to pelagic organism decline (POD) in the San Francisco Estuary (Dugdale et al. 2007).

To obtain more data on the critical region downstream of the Sacramento wastewater treatment plant (SRWTP), water samples were collected along ~30 transects of the Sacramento River (SR) from July 2008 to April 2010. Depending on transect, water samples were collected from 6-25 sites extending from >10 miles upstream of SRWTP downstream to Rio Vista and usually further downstream. Data were also obtained from an additional 8 sites between Rio Vista and Angel Island from monthly excursions by the USGS RV Polaris. All samples were analyzed for EC, nutrients, chlorophyll, and many were also analyzed for DOC, DON, and N and C uptake rates. A comprehensive suite of isotope analyses has been made for 3 transects and analyses of samples from other transects are in progress. Efforts thus far have focused on evaluating (1) how NH4, NO3, and organic matter concentrations vary under different hydrologic conditions, and (2) how nitrification rates (the main biogeochemical process responsible for lowering NH4 levels) vary seasonally and in different reaches of the SR and upper estuary. Examination of these transects has revealed that NH4 and NO3 concentrations at any particular site and date downstream of SRWTP are the product of a large number of time-varying factors, including flow, interruptions in effluent discharge, apparent variations in effluent composition, water chemistry upstream of SRWTP, nitrification rates, and changing inputs from tributaries, the San Joaquin River, and point-sources to the Bay. This kind of detailed examination of processes along transects complements the statistical approaches (Glibert 2010) and lumped approaches (Foe et al. 2010) currently being utilized to evaluate the linkage between NH4, algae, and POD.

Kendall, C., M. Guerin, T. Kraus, M. Young, S. Silva, A. Parker, and C. Foe (2010). Causes of temporal and spatial variations in nitrification rates in the Sacramento River and Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
High concentrations of NH4 have been hypothesized to suppress phytoplankton blooms, contributing to pelagic organism decline in the San Francisco Estuary (Dugdale et al. 2007). Nitrification of effluent largely derived from the Sacramento wastewater treatment plant (SRWTP) appears to be the dominant process responsible for lowering NH4 concentrations. Therefore, a better understanding of the biogeochemical and hydrological controls on nitrification rates should facilitate development of improved remediation strategies. We used data from over half of the 30 transects of the Sacramento River conducted July 2008 to April 2010 for our nitrification analysis. Isotope fractionation factors have been compared to nitrification rates for 3 transects. Preliminary analyses using multiple linear regressions to predict downstream NH4 concentrations at Rio Vista suggest that the main controlling factors are river flow, the volumetric fraction of flow from SRWTP, water temperature, and upstream NO3 concentration. We calculated rates for both conversion of NH4 to NO2 and NO2 to NO3 using two approaches, both using travel times calculated with DSM2. One method used a recursive approach to find a decay rate that minimized the percent difference in calculated versus measured concentrations for NH4 and NO3. The average decay rates for NH4 to NO2 and for NO2 to NO3 were consistent with literature values, and the rates generally decreased downstream of Rio Vista. The second method used the measured changes in nutrients and interpolated travel times between adjacent sites to calculate rates, resulting in a much wider spatial and temporal range of rates. Differences in measured and calculated rates and between the rates of the two different nitrification steps are interpreted in terms of additional sources and sinks of nutrients, using isotope data as constraints. The much greater losses in NH4 compared to gains in NO3 and NO2 between adjacent sites suggests significant additional sinks of nutrients.

Kendall, C., M. Young, S. Silva, T.Kraus, A. Parker, and M. Guerin (2010). Impact of waste water effluent on the temporal and spatial distributions of nutrients and organic matter in the San Francisco Estuary. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Kendall, C., S. Silva, M. Young, M. Guerin, A. Parker, and C. Foe (2010). Seasonal and spatial variation in water chemistry and isotopes in the Sacramento River, Delta, and eastern San Francisco Bay. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
High concentrations of NH4 have been hypothesized to suppress phytoplankton blooms, contributing to pelagic organism decline in the San Francisco Estuary (Dugdale et al. 2007). To obtain more data on the critical region downstream of the Sacramento wastewater treatment plant (SRWTP), water samples were collected along ~30 transects of the Sacramento River (SR) from July 2008 to April 2010. Depending on transect, water samples were collected from 6-25 sites extending from >10 miles upstream of SRWTP downstream to Rio Vista and usually further downstream. Data were also obtained from an additional 8 sites between Rio Vista and Angel Island from monthly excursions by the USGS RV Polaris. All samples were analyzed for EC, nutrients, chlorophyll, and many were also analyzed for DOC, DON, and N and C uptake rates. Samples from 3 transects have been analyzed for a comprehensive suite of isotopes, and analyses of isotope samples from other transects are in progress. Isotope data are proving very useful for testing hypotheses developed based on the chemistry and other data. DSM2-derived volumetric, stage, and net flow data are available for most transects, providing an additional constraint on interpretations of the variability. Datasets such as these are usually evaluated for spatial trends using average values at sites, by plotting various constituents versus river mile or salinity for each transect, or by statistical analyses of variance. We have found that these methods are much less effective than color contour diagrams that plot spatial and temporal variations in chemistry, isotopes, hydrologic measurements, and DSM2 results for identifying data trends and suggesting sources and processes. The main cause of spatial and temporal variation in NH4 and NO3 concentrations is nitrification. This poster will present a variety of contour plots with preliminary interpretations about likely causes of the some of the main spatial and temporal patterns in the chemistry of the San Francisco estuary.

Kendall, C., S. Silva, and P.W. Lehman (2010). Use of stable isotopes for evaluating environmental conditions associated with Microcystis blooms in the Delta. 6th Biennial Bay–Delta Science Conference, Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The toxic cyanobacteria Microcystis aeruginosa first appeared in the San Francisco San Joaquin Delta in 1999, and now poses a serious water quality concern. As part of a larger study aimed at determining the impact of Microcystis on ecosystem structure and function, human and wildlife health, and environmental conditions in the Sacramento-San Joaquin River Delta, isotope samples were collected from 12 sites that were experiencing annual Microcystis blooms. These sites represented a range of typical fresh and brackish water habitats. All sites were sampled every two weeks in summer 2007 and in January 2008, and 5 were also sampled every two weeks in summer 2008. All samples were analyzed for d15N, d13C, and C:N of seston, and d18O and d2H of water. A subset was analyzed for d13C of dissolved organic matter (DOM), and samples were archived for future nitrate and DOM isotope analyses. The goal of the study was to evaluate the usefulness of isotopes for answering questions such as: what is the source of the Microcystis biomass (internal islands or external rivers), what is the source of N utilized by Microcystis, and does Microcystis affect the quality of the DOM available for the microbial food web. As seen in earlier CALFED-funded studies of organic matter in the Delta, we find that seston and DOM show seasonal and spatial variations in isotopic composition related to source of the organic matter (terrestrial/macrophyte vs algae), the source of the N used by the algae, and biogeochemical processes affecting dissolved nitrogen and carbon species. Two sites, Antioch and Collinsville, showed strong inverse correlations of seston d15N and C:N, and positive correlations of d15N and [NH4] and/or [NO3]. Other sites showed more complex correlations among seston d13C and d15N, chlorophyll concentrations, and nutrient levels.

Kendall, C. (2010). Usefulness of stable isotopic techniques for environmental monitoring programs. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Kennedy, D. N. (1995). Sacramento-San Joaquin Delta Atlas. Sacramento Ca. (see also http://baydeltaoffice.water.ca.gov/DeltaAtlas/ Sacramento-San Joaquin Delta Atlas. Sacramento, CA, California Department of Water Resources: 121.
This atlas provides information that we hope will be helpful in addressing the complex problems of the estuary. This atlas is a revision of the Sacramento-San Joaquin Delta Atlas that was published in 1987. It contains updates on many Delta facts and features. It also introduces new information on the Suisun Marsh and tides and hydrology in the Delta as well as in San Francisco Bay.

Khan, A., and A. Schwarz (2010). Climate change characterization in California Water Resources planning studies. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The mission of the California Department of Water Resources (DWR) is to manage the water resources of California, in cooperation with other agencies, to benefit the State’s people, and to protect, restore, and enhance the natural and human environments. To fulfill its mission, DWR leads or participates with other agencies in various planning studies. The studies range from the California Water Plan, which provides general long-term information about California water resources, to Environmental Impact Reports for specific water management projects. Many of these planning studies require an analysis of future conditions including climate and hydrology. Historical planning practices that assume that past observations of climate and hydrology were reasonable predictors of future conditions have been called into question because of climate change. As a result, recent water resources planning in California, as in other States, involves the development of new approaches to forecast future climate and hydrology. DWR does not currently have a standard approach or a set of recommended approaches for considering climate change in its planning studies. Of the studies underway, we generally follow one of several approaches that include: 1) A methodology based on 12 Global Climate Model (GCM) simulations selected for the California Climate Action Team 2009 Impacts Report; 2) An Ensemble Informed Approach based on all of the 112 available simulations from the IPCC AR4 (2007); 3) Sensitivity analysis using data from one or a few GCM simulations; 4) Delta approach that superimposes in its analysis the impact variance between alternatives evaluated in another, similar study incorporating GCM based data; and 5) Qualitative approaches. This paper reviews and summarizes these climate change characterization approaches used in recent planning studies conducted by DWR and participating agencies. The information is intended for use by DWR and others to consider how to include climate change analyses in different studies and identify opportunities for developing and using common approaches for studies with similar goals and assumptions.

Khanna, S., M.J. Santos, E.L. Hestir, and S.L. Ustin (2010). Vegetation Community dynamics relative to the changing distribution of water hyacinth in the Sacramento-San Joaquin Delta. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The spread of invasive alien species (IAS) has resulted in enormous economic and ecological costs across the world. As costs of control and eradication efforts for IAS increase, it is important to assess whether such actions are having the desired effect. Eradication or control of a dominant invasive species in an ecosystem can frequently have unintended consequences such as facilitation in spread of other invasive species, loss of ecosystem function or loss of other native species being supported by the targeted invasive. We illustrate this conundrum through the example of a well-known invasive aquatic macrophyte, water hyacinth (Eichhornia crassipes), in the Sacramento-San Joaquin Delta in California which has negatively impacted the Delta ecosystem. Using the Optimal Scale Change Detection (OSCD) technique on five years of classified hyperspectral remote sensing imagery, we look at vegetation community dynamics in the Delta in regions of changing water hyacinth cover. Our results show that as water hyacinth cover decreases, submerged aquatic plant (SAP) cover increases and vice versa. This effect is stronger in larger patches of water hyacinth compared to smaller patches. We found no evidence that the native species, pennywort (Hydrocotyle umbellata) is benefiting from

shrinking water hyacinth patches. In most years, pennywort cover either showed no trend or followed the same growth trajectory as water hyacinth i.e. increasing or decreasing with water hyacinth cover. Thus, in the Delta, a decrease in water hyacinth has led to re-colonization by submerged species with some habitat returning to open water. It has not promoted the spread of native pennywort.

Kim, J. T., K.M. Parker, and P.W. Hedrick (1999). "Major histocompatibility complex differentiation in Sacramento River chinook salmon " Genetics 151(3): 1115-1122.
The chinook salmon of the Sacramento River, California, have been reduced to a fraction of their former abundance because of human impact and use of the river system. Here we examine the genetic variation at a major histocompatibility complex class II exon in the four Sacramento chinook salmon runs. Examination of the alleles found in these and other chinook salmon revealed nucleotide patterns consistent with selection for amino acid replacement at the putative antigen-binding sites. We found a significant amount of variation in each of the runs, including the federally endangered winter run. All of the samples were in Hardy-Weinberg proportions. A significant amount of genetic differentiation between runs was revealed by several measures of differentiation. Winter run was the most genetically divergent, while the spring, late-fall, and fall runs were less differentiated.

Kimmerer, W., E. Gross, et al. (2009). "Is the Response of Estuarine Nekton to Freshwater Flow in the San Francisco Estuary Explained by Variation in Habitat Volume?" Estuaries and Coasts 32(2): 375-389.
Abundance of estuarine biota can vary with freshwater inflow through several mechanisms. One proposed mechanism is that the extent of physical habitat for an estuarine species increases with flow. We estimated the contribution of variation in habitat volume to the responses of eight species of estuarine nekton to changes in freshwater flow in the San Francisco Estuary. Resource selection functions for salinity and depth were developed for each species (and for five additional species) using five monitoring data sets. The TRIM3D hydrodynamic model was run for five steady flow scenarios to determine volume by salinity and depth, and resource selection functions were used as a weighting factor to calculate an index of total habitat for each species at each flow. The slopes of these habitat indices vs. flow were consistent with slopes of abundance vs. flow for only two of the species examined. Therefore, other mechanisms must underlie responses of abundance to flow for most species.

Kimmerer, W., D. Murphy, et al. (2005). "A landscape-level model of the San Francisco Estuary and its watershed." San Francisco Estuary and Watershed Science (Online Serial) 3(1): Article 2.

Kimmerer, W., A. Parker, et al. (2012). "Short-Term and Interannual Variability in Primary Production in the Low-Salinity Zone of the San Francisco Estuary." Estuaries and Coasts 35(4): 913-929.
In this paper we examined primary productivity in the Low-Salinity Zone during 2006 and 2007, years of contrasting hydrology, and used monitoring data to place this study in a long-term context. Primary production was low during the entire period and affected remarkably little by freshwater flow. About half of the production was in cells smaller than 5 micrometers, implying low foodweb efficiency and very little support to higher trophic levels.

Kimmerer, W. J., S.V. Smith, and J.T. Hollibaugh (1993). "A simple heuristic model of nutrient cycling in an estuary." Estuarine, Coastal and Shelf Science 37(2): 145-159.
Three decades of discussion and study have not resolved the apparent discrepancy between N-limitation of primary production and the ability of marine ecosystems to fix N. We use a simple model as a heuristic tool to examine controls on nutrient cycling in a shallow estuary, with Tomales Bay, California as the prototype. The model is a steady-state, one-box model with inputs and losses of nutrients and organic matter, and terms representing N-fixation and denitrification. The physical description of the system is deliberately kept simple to permit a focus on the key biogeochemical reactions. Growth of autotrophs in the model can be limited either by dissolved inorganic nitrogen (DIN) or dissolved inorganic

phosphorus (DIP). Nitrogen-fixation is controlled by the availability of DIP or limited by excess amounts of DIN. Model results demonstrate that, for a system with a long residence time, autotroph biomass and total organic matter are controlled primarily by the rate of delivery of P to the system, either as DIP or in organic matter. Increasing the delivery rate of DIN raises autotroph biomass slightly but has little effect on total organic matter. This is because the rates of input of P as DIP or organic matter control the N-fixation rate, and denitrification limits the build-up of DIN in the system. Thus, denitrification and N-fixation act as opposing negative feedbacks, insuring that the supply of N remains roughly commensurate with that of P. When exchange with the ocean is increased, reducing residence time, the relative importance of DIN input increases relative to that of DIP.

Kimmerer, W. J., E. Gartside, and J.J. Orsi. (1994). "Predation by an introduced clam as the likely cause of substantial declines in zooplankton of San Francisco Bay." Marine Ecology Progress Series 113: 81-93.

The clam Potamocorbula amurensis was introduced into the San Francisco Bay estuary (California, USA) in 1986 and became abundant in late 1987. Within a year, chlorophyll concentration and the abundance of adults of 3 common estuarine copepod species had declined by 53 to 91 %, providing an opportunity to examine mechanisms by which benthic grazing might control the abundance of pelagic populations. Declines in chlorophyll and abundance of the 3 species of copepod coincided approximately with the geographic range of the clam population. The decline in abundance of the copepod Eurytemora affinis was accompanied by a decrease in the ratio of nauplii to adults, but not in the ratio of eggs to females. Therefore the decline in abundance may be due to elevated mortality of nauplii rather than food limitation of reproductive rate. We argue that direct predation by P. amurensis is the cause of the reduced survival of nauplii, and therefore of the depressed abundance of adults. Experimentally determined clearance rates of P. amurensis on E. affinis nauplii averaged 0. 11 l clam-1d -1. If that clearance rate applied in the field, the clams could remove 8.2 % of the nauplii d ^-1. This removal rate is sufficient to explain the observed rate of population decline. P. amurensis appears to have become well established and copepod populations of the bay so far have failed to rebound. Thus this invasion may have permanent effects. In a broader sense, predation on zooplankton by soft-bottom benthos may be an important and heretofore overlooked, source of mortality in shallow waters. Selectivity occurring through differences in escape response and vertical position could make bivalve predation an important influence on biomass and species composition of inshore zooplankton.

Kimmerer, W. J., and J. J. Orsi. (1996). Causes of long-term declines in zooplankton in the San Francisco Bay estuary since 1987. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science
AAAS: 403-424.

The zooplankton of the northern San Francisco Bay estuary has been characterized over the last 2 decades by long-term declines in abundance of some species, and introductions of others. The most striking change occurred in 1987-88, concurrent with the spread of the introduced clam Potamocorbula amurensis. Previous work presented evidence suggesting that declines in some copepod species were caused by the clam, more by predation on nauplii than by competition for food. Here we show that the clam probably caused a decline in other species of zooplankton, and that the large decline in Neomysis mercedis was probably due to competition with P. amurensis for food. At the time of these declines in zooplankton the copepod Pseudodiaptomus forbesi became abundant over much of the region formerly occupied by the previously common copepod Eurytemora affinis. Based on present data, we cannot explain this apparent coincidence in timing, but assume it was due to a competitive interaction. Although much of the post-clam period was characterized by drought, the low freshwater flows of that period do not explain the reduction in chlorophyll or zooplankton abundance. The high flows of 1993 caused a temporary reduction in abundance of P. amurensis, but the larger size of the clams made up for the reduction in numbers, and by summer the zooplankton populations were again low. The change in zooplankton distribution and abundance may persist into the future; however, it is not clear that higher trophic levels are being adversely affected.

Kimmerer, W. J., and J. J. Orsi. (1996). Changes in the zooplankton of the San Francisco Bay estuary since the introduction of the clam Potamocorbula amurensis. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science: 403-425.

Kimmerer, W. J. (1998). Report of the 1994 Entrapment Zone Study. Sacramento, Interagency Ecological Program for the San Francisco Bay/Delta Estuary.

Kimmerer, W. J., J.R. Burau, and W.A. Bennett. (1998). "Tidally oriented vertical migration and position maintenance of zooplankton in a temperate estuary." Limnology and Oceanography 43(7): 1697-1709.

In many estuaries, maxima in turbidity and abundance of several common species of zooplankton occur in the low salinity zone (LSZ) in the range of 0.5-6 practical salinity units (psu). Analysis of zooplankton abundance from monitoring in 1972-1987 revealed that historical maxima in abundance of the copepod Eurytemora affinis and the mysid Neomysis mercedis, and in turbidity as determined from Secchi disk data, were close to the estimated position of 2 psu bottom salinity. The copepod Sinocalanus doerri had a maximum slightly landward of that of E. affinis. After 1987 these maxima decreased and shifted to a lower salinity, presumably because of the effects of grazing by the introduced clam Potamocorbula amurensis. At the same time, the copepod pseudodiaptomus forbesi, the mysid Acanthomysis sp., and amphipods became abundant with peaks at salinity around 0.2-0.5 psu. Plausible mechanisms for maintenance of these persistent abundance peaks include interactions between variation in flow and abundance, either in the vertical or horizontal plane, or higher net population growth rate in the peaks than seaward of the peaks. In spring of 1994, a dry year, we sampled in and near the LSZ using a Lagrangian sampling scheme to follow selected isohalines while sampling over several complete tidal cycles. Acoustic Doppler current profilers were used to provide detailed velocity distributions to enable us to estimate longitudinal fluxes of organisms. Stratification was weak and gravitational circulation nearly absent in the LSZ. All of the common species of zooplankton migrated vertically in response to the tides, with abundance higher in the water column on the flood than on the ebb. Migration of mysids and amphipods was sufficient to override net seaward flow to produce a net landward flux of organisms. Migration of copepods, however, was insufficient to reverse or even greatly diminish the net seaward flux of organisms, implying alternative mechanisms of position maintenance.

Kimmerer, W. J., J.H. Cowan, Jr., L.W. Miller, and K.A. Rose. (2001). "Analysis of an estuarine striped bass population: effects of environmental conditions during early life." Estuaries and Coasts 24(4): 557-575.

Estuarine fish populations are exposed to a variety of environmental conditions that cause both short-term variability and long-term trends in abundance. We analyzed an extensive data set for striped bass (Morone saxatilis) in the San Francisco Estuary to refine our understanding of how environmental variability influences recruitment. We examined the effects of environmental variability during early life stages on subsequent recruitment (age 3 yr), and the degree to which conditions in early life may have contributed to a long-term decline in abundance of adult striped bass in the San Francisco Estuary. Survival from egg to young-of-the-year varied strongly with freshwater flow; this effect apparently occurred within the first week or two of life, a time period that encompasses transport of eggs and larvae from the rivers to rearing areas and the onset of feeding. The rate of freshwater flow to pumping facilities that export freshwater from the system had small or sporadic effects on survival during the first month or two of life. Although many young striped bass between ages 2 and 8 mo were entrained in export pumping facilities, the resulting high mortality was unrelated to total mortality rates determined from field data on young striped bass. This lack of effect was apparently due to strong density-dependent mortality occurring between ages 1 mo and 3 yr (Kimmerer et al. 2000). The available data do not support previously suggested relationships between recruitment and freshwater flow during early life, or between gross estimates of pesticide input and survival of early life stages. We used a simple life-cycle model to show that various combined factors could have led to a decline in adult abundance, particularly a large and increasing adult mortality, but that events early in life probably did not contribute substantially to the decline. These results demonstrate that several decades of monitoring data from numerous life stages are needed to distinguish among alternative hypotheses about environmental influences on populations of estuarine fish.

Kimmerer, W. J., B. Mitchell, and A. Hamilton (2001). Building models and gathering data: Can we do this better? Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 305-318.

We are constructing a “second generation” model of chinook salmon for the Sacramento Basin to help investigate factors affecting salmon populations and the effects of management actions. We chose to build a new model rather than modify an older one to apply recent developments in computer interfaces and individual-based modeling and to incorporate a more detailed and flexible geographic representation. We also expected that substantial new knowledge had been developed that would enable us better to characterize the life cycle and influences on survival of chinook salmon. These expectations have not been met, and despite some recent progress we still find gaps between the knowledge available and that needed for successful modeling. Key examples of gaps in our knowledge include sublethal temperature effects, abundance of young fish, factors triggering migration, factors limiting rearing habitat, and survival of young salmon, particularly fry rearing in the mainstem or Delta reaches and early survival in the ocean. We believe these gaps arise for several reasons: (1) a mismatch in perceptions of what data are needed; (2) a lack of institutional commitment to long-term, broad-scale programs to provide knowledge useful in modeling; and (3) the fundamental difficulty of gathering information about environmental influences on fish populations.

Kimmerer, W. J. (2002). "Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages?" Marine Ecology Progress Series 243: 39-55.

All ecosystems are influenced by physical forcing. Estuarine ecosystems respond most strongly on an interannual timescale to variability in freshwater flow. Several mechanisms for positive or negative flow effects on biological populations in estuaries have been proposed; however, positive effects appear to operate mainly through stimulation of primary production with effects propagating up the food web. In the northern San Francisco Estuary, abundance or survival of several common species of fish and shrimp varied positively with flow-in data through 1992. I re-examined these relationships and those of several additional taxa in an analysis of long-term (20 to 40 yr) monitoring data. The spread of the introduced clam Potamocorbula amurensis in 1987 provided an opportunity to examine simultaneously the responses of estuarine species to flow and to changes in the food web. I separated variability into a flow response, a step change after 1987 and other sources of variability. Responses of fish and shrimp contrasted with those of lower trophic levels. All but 1 species of nekton responded positively to flow, only 2 had clear declines after 1987, and none of the relationships changed in slope after 1987. In contrast with the higher trophic levels, chlorophyll a (chl a) and several species of zooplankton declined markedly after 1987, and had either weak responses to flow or responses that changed after 1987. Thus, the food web appears strongly coupled between benthos and plankton, and weakly coupled between zooplankton and fish, as has been found in other systems. More importantly, the variation with freshwater flow of abundance or survival of organisms in higher trophic levels apparently did not occur through upward trophic transfer, since a similar relationship was lacking in most of the data on lower trophic levels. Rather, this variation may occur through attributes of physical habitat that vary with flow.

Kimmerer, W. J., J.R. Burau, and W.A. Bennett. (2002). "Persistence of tidally-oriented vertical migration by zooplankton in a temperate estuary." Estuaries and Coasts 25(3): 359-371.

Tidal vertical migration by zooplankton is a common phenomenon in estuaries, usually associated with landward movement of meroplankton or position maintenance of holoplankton. Little is known about the persistence of this behavior, its spatial variability, or its response to changing environmental conditions. We extended a previous study of tidal movements of zooplankton in the low-salinity zone (LSZ) of the San Francisco estuary in 1994 to include data from two additional years with very different hydrology. Freshwater flow during sampling in 1995 was about 7-fold greater than in 1994; the LSZ was about 28 km further seaward, and gravitational circulation in the LSZ was strong. In 1996 freshwater flow and LSZ position were intermediate but, because the LSZ was in shallower water in 1996 than in 1995, gravitational circulation was uncommon. Behavior of copepods in both years was similar to that reported in 1994 with some tidal migration observed during most cruises. An exception was the introduced carnivorous copepod Tortanus dextrilobatus, which did not migrate and maintained a position deep in the water column (1995 only). In 1996, mysids mainly stayed near the bottom with evidence for vertical migration from only 1 of 6 data sets, whereas amphipods migrated slightly on a diel schedule; these behaviors contrasted with the tidal migration observed in 1994. The bay shrimp Crangon franciscorum did not appear to migrate, but was more abundant in the water column during both ebb and flood, suggesting passive vertical dispersal. Zooplankton did not appear to maintain position by interactions with lateral circulation cells. The results for copepods suggest rigidity in behavior with little or no relaxation of the vertical movement in 1995 when strong gravitational circulation would have made upstream movement relatively easy. Mysids and amphipods altered their behavior depending on local conditions related to freshwater flow.

Kimmerer, W. J. (2002). "Physical, biological, and management responses to variable freshwater flow into the San Francisco Estuary." Estuaries and Coasts 25(6): 1275-1290.

Freshwater flow is the principal cause of physical variability in estuaries and a focus of conflict in estuaries where a substantial fraction of the freshwater is diverted. Variation in freshwater flow can have many effects: inundation of flood plains, increase loading and advective transport of materials and organisms, dilution or mobilization of contaminants, compression of the estuarine salinity field and density gradient, increase in stratification, and decrease in residence time for water while increasing it for some particles and biota. In the San Francisco Estuary, freshwater flow is highly variable, and has been altered by shifts in seasonal patterns of river flow and increases in diversions from tidal and nontidal regions, entraining fish of several species of concern. Abundance or survival of several estuarine-dependent species also increases with freshwater outflow. These relationships to flow may be due to several potential mechanisms, each with its own locus and period of effectiveness, but no mechanism has been conclusively shown to underlie the flow relationship of any species. Several flow-based management actions were established in the mid-1990s, including a salinity standard based on these flow effects, as well as reductions in diversion pumping during critical periods for listed species of fish. The effectiveness of these actions has not been established. To make the salinity standard more effective and more applicable to future estuarine conditions will require investigation to determine the underlying mechanisms. Effects of entrainment at diversion facilities are more straightforward conceptually but difficult to quatify, and resolving these may require experimental manipulations of diversion flow.

Kimmerer, W. J. (2004). "Open water processes of the San Francisco Estuary: From physical forcing to biological responses." San Francisco Estuary and Watershed Science (Online Serial) 2(1): Issue 1, Article 1. http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1.

Kimmerer, W. J. (2005). "Long-term changes in apparent uptake of silica in the San Francisco estuary." Limnology and Oceanography 50: 793-798.

Kimmerer, W. J., S. Avent, S. Bollens, F. Feyrer, L. Grimaldo, P.B. Moyle, M.L. Nobriga, and T. Visintainer (2005). "Variability in length-weight relationships used to estimate biomass of estuarine fishes from survey data." Transactions of the American Fisheries Society 134: 481-495.

The biomass of fish populations is often calculated from abundance-by-length data using length-weight (LW) relationships from separate studies (e.g., from the literature). Estimates of biomass determined this way have twoprincipal sources of error: (1) error in total numbers and size distribution of fish due to sampling variability; and (2) prediction error, including that arising from the use of a LW relationship from another time, place, population, or species. We developed LW relationships from 6,390 measurements of fish of 24 species in the San Francisco Estuary. Our principal objective was to evaluate the errors that arise when calculating biomass from length data. Data were obtained from four sampling studies (none designed for this purpose) and analyzed with analysis of covariance on log-transformed data. Differences in LW relationships among studies were apparent. Five tests were applied to assess the influence of these differences on predictions of biomass from length data. Three of these tests indicated some bias arising from several sources, including differences in the range of lengths used to develop the relationships. The remaining two tests compared the sampling variability of two common fish species with variability and bias introduced by means of different alternative LW relationships from our data and from the literature. Length-weight relationships from the literature introduced some bias and somewhat more variability into the biomass estimates compared with estimates based on LW relationships obtained from the San Francisco Estuary. However, sampling error was the largest source of error in all cases. Although it is preferable to calculate biomass from LW relationships of fish from the same area and time period, the error induced by using relationships from other time periods, other areas, or the literature is typically small compared with sampling error, particularly when only relative measures of biomass are needed.

Kimmerer, W. J. (2006). "Response of anchovies dampens effects of the invasive bivalve Corbula amurensis on the San Francisco Estuary foodweb." Marine Ecology Progress Series 324: 207-218.
        Introduced bivalves have suppressed phytoplankton production in many aquatic foodwebs, but effects on higher trophic levels have been inconsistent. In the northern San Francisco Estuary, the introduced clam Corbula amurensis eliminated summer-long phytoplankton blooms starting in 1987, but responses of mesozooplankton biomass and most fish were somewhat muted. I conducted a retrospective analysis of the response of the estuarine foodweb to the decline in phytoplankton due to clam grazing. When C. amurensis invaded, the distribution of northern anchovy Engraulis mordax shifted toward higher salinity, reducing summer abundance by 94% in the low-salinity region of the estuary. Northern anchovy dominates the biomass of fish in the more saline reaches of the estuary, and is genetically affiliated with the subpopulation on the central California coast, which in turn is strongly influenced by climate variability. However, abundance of northern anchovy within the estuary was not related to available estimates of biomass, catch, or abundance of northern anchovy on the California coast, nor was it related to any of 4 variables describing aspects of climate variability with different time and space scales. The shift in spatial distribution appears to have been a direct behavioral response to reduced food. Bioenergetic calculations showed reduced consumption of zooplankton by all planktivores, including mysids, after C. amurensis became abundant and the anchovy left the low-salinity region of the estuary. This reduced consumption appears to have mitigated effects of the loss of phytoplankton productivity, making a greater proportion of the zooplankton productivity available to other fish species. Such behavioral accommodations are likely wherever invasions occur in open systems.

Kimmerer, W. J. (2008). "Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta." San Francisco Estuary and Watershed Science 6(2): Issue 2 Article 2.
        Pumping at the water export facilities in the southern Sacramento-San Joaquin Delta kills fish at and near the associated fish-salvage facilities. Correlative analyses of salvage counts with population indices have failed to provide quantitative estimates of the magnitude of this mortality. I estimated the proportional losses of Sacramento River Chinook salmon (Oncorhynchus tshawytscha) and delta smelt (Hypomesus transpacificus) to place these losses in a population context. The estimate for salmon was based on recoveries of tagged smolts released in the upper Sacramento River basin, and recovered at the fish-salvage facilities in the south Delta and in a trawling program in the western Delta. The proportion of fish salvaged increased with export flow, with a mean value around 10% at the highest export flows recorded. Mortality was around 10% if pre-salvage losses were

about 80%, but this value is nearly unconstrained. Losses of adult delta smelt in winter and young delta smelt in spring were estimated from salvage data (adults) corrected for estimated pre-salvage survival, or from trawl data in the southern Delta (young). These losses were divided by population size and accumulated over the respective seasons. Losses of adult delta smelt were 1–50% (median 15%) although the highest value may have been biased upward. Daily losses of larvae and juveniles were 0–8%, and seasonal losses accumulated were 0–25% (median 13%). The effect of these losses on population abundance was obscured by subsequent 50-fold variability in survival from summer to fall.

Kimmerer, W. J., Parker, A., J. Thompson, G. McManus, J. York, A. Gould, V. Greene, U. Lidstrom, A. Slaughter, and T. Ignoffo (2010). The pelagic foodweb of the upper San Francisco Estuary: changing conditions and changing understanding. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

A contributing factor to the Pelagic Organism Decline may be the low abundance of copepods in the low-salinity zone (LSZ), which may limit growth or survival of delta smelt and other pelagic fish. This low abundance is believed due to low productivity of the LSZ foodweb. A multidisciplinary study over the last four years has provided some insights into the functioning of this foodweb. Primary production was lower than expected from chlorophyll concentration, a finding consistent with the low carbon:chlorophyll ratio of ~20 in 2006-2007. About 60% of the primary production was in particles smaller than 5 μm, near the lower limit of particle size grazed upon efficiently by copepods or by the clam Corbula amurensis. Both of these findings indicate a shift toward smaller, slower-growing phytoplankton. Ciliates were consumed at high rates by both copepods and clams and were apparently limited more by predation than by food supply. Copepods, by contrast, were persistently food limited. Specific growth rates in summer were low for Limnoithona tetraspina and variable but usually low for Pseudodiaptomus forbesi, while egg production rates of both species were always low. Calculated consumption of phytoplankton, ciliates, and P. forbesi by clams exceeded the reproductive capacities of all groups, requiring transport from other regions of the estuary. Taken together, these results show a foodweb that is severely limited in its capacity to support pelagic fish and that may degrade further if subsidies from other parts of the estuary become impaired.

Kimmerer, W. J. (2011). "Modeling Delta Smelt Losses at the South Delta Export Facilities." San Francisco Estuary and Watershed Science 9(1).

Kimmerer, W. J., J. H. J. Cowan, et al. (2000). "Analysis of an estuarine striped bass (Morone saxatilis) population: Influence of density-dependent mortality between metamorphosis and recruitment." Canadian Journal of Fisheries and Aquatic Sciences 57(2): 478-486.

Compensation due to density-dependent mechanisms is essential for the maintenance of an exploited fish stock. Understanding compensation is important for understanding population regulation and responses to added mortality. We examined possible density-dependent effects on striped bass (Morone saxatilis) in the San Francisco Estuary. Three sets of data from sampling programs for young striped bass showed density-dependent mortality between 1 month of age and 8-12 months. The relationships between two indices of young striped bass abundance and recruitment at age 3 fit a Beverton-Holt function, also indicating density dependence. The carrying capacity, as determined by the asymptote of the Beverton-Holt curves, has declined over the last two to three decades. These results are consistent with a compensatory mechanism based on food limitation occurring after metamorphosis and with the decline in food resources observed in the estuary over the same period. The decline in striped bass over the last two to three decades may be partly due to this declining carrying capacity.

Kimmerer, W. J. and A. L. Gould (2010). "A Bayesian approach to estimating copepod development times from stage frequency data " American Society of Limnology and Oceanograph Methods(8): 118-126.

We developed Bayesian hierarchical models to estimate life stage durations of copepods from data on life stage frequencies over time in laboratory cohorts.

This approach can determine stage duration or development rate, as well as other parameters of the development process, with probability distributions for each parameter. Uncertainty arising from sources such as experimental replication and the variability inherent in count data can easily be incorporated. Prior probability distributions can be uninformative, or they can apply constraints (e.g., stage durations > 0), general knowledge of development, or results of previous experiments. The approach is flexible, with the capability to model any number of life stages from experiments using replicated or unreplicated designs. We verified the model by accurately recovering the life stage distributions used to produce data in a simulation. We then applied the method to laboratory data on the development of two calanoid copepods and one cyclopoid copepod from the San Francisco Estuary. With replication (3 or 4 replicates), the method can determine stage durations with ~30 copepods per sample, although the uncertainty around estimates of stage duration increases as the number of copepods per sample decreases or the sampling interval increases.

Kimmerer, W. J., M. H. Nicolini, et al. (2005). "Chronic food limitation of egg production in populations of copepods of the genus Acartia in the San Francisco Estuary." Estuaries 28: 541-550.

Kimmerer, W. J. and M. N. Nobriga (2008). "Investigating particle transport and fate in the Sacramento-San Joaquin Delta using a particle tracking model." San Francisco Estuary and Watershed Science 6(1): Issue 1 Article 4.
Movements of pelagic organisms in the tidal freshwater regions of estuaries are sensitive to the movements of water. In the Sacramento-San Joaquin Delta—the tidal freshwater reach of the San Francisco Estuary—such movements are key to losses of fish and other organisms to entrainment in large water-export facilities. We used the Delta Simulation Model-2 hydrodynamic model and its particle tracking model to examine the principal determinants of entrainment losses to the export facilities and how movement of fish through the Delta may be influenced by flow. We modeled 936 scenarios for 74 different conditions of flow, diversions, tides, and removable barriers to address seven questions regarding hydrodynamics and entrainment risk in the Delta. Tide had relatively small effects on fate and residence time of particles. Release location and hydrology interacted to control particle fate and residence time. The ratio of flow into the export facilities to freshwater flow into the Delta (export:inflow or EI ratio) was a useful predictor of entrainment probability if the model were allowed to run long enough to resolve particles' ultimate fate. Agricultural diversions within the Delta increased total entrainment losses and altered local movement patterns. Removable barriers in channels of the southern Delta and gates in the Delta Cross Channel in the northern Delta had minor effects on particles released in the rivers above these channels. A simulation of losses of larval delta smelt showed substantial cumulative losses depending on both inflow and export flow. A simulation mimicking mark-recapture experiments on Chinook salmon smolts suggested that both inflow and export flow may be important factors determining survival of salmon in the upper estuary. To the extent that fish behave passively, this model is probably suitable for describing Delta-wide movement, but it is less suitable for smaller scales or alternative configurations of the Delta.

Kimmerer, W. J. and J. R. Schubel (1994). Managing freshwater flows into San Francisco Bay using a salinity standard: results of a workshop. Changes in fluxes in estuaries: implications from science to management. K. R. Dyer and R. J. Orth. Fredensborg, Denmark, Olsen and Olsen: 411-416.

Kiparsky, M., W. Collins, D. Groves, B. Joyce, D. Purkey, and C. Young (2010). Water resources sensitivity to climate change, land use change, and population growth in the Stanislaus, Tuolumne and Merced Basins. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Studies of climate change impacts on hydrology and water operations have become increasingly popular over the past decade, and have yielded insights into system sensitivity to climate-impacted hydrologic regimes. The goal of this study is to integrate projections of such climate change impacts with other anthropogenic changes that will occur in parallel, in particular urbanization and population

growth. We built an integrated hydrology and water operations model of the Stanisulas, Tuolumne, and Merced River Basins using the WEAP platform. We ran the model using an ensemble of 12 downscaled GCM scenarios, and spatially explicit projections of urbanization and population growth through the year 2099. Results are described separately and in combination. Consistent with other studies, climate change alone results in increasing water demands and decreasing water supply reliability by mid-century. Adding population growth and urbanization results in decreasing demands, as agricultural land is taken out of production and replaced with low-density residential uses. In this rapidly urbanizing agricultural area, the combined effect is a decrease in total water demands, and concomitant increase in water supply reliability under climate change with population growth. The results suggest that multiple anthropogenic stressors will act in concert to produce impacts on water systems different from individual stressors considered alone. The results highlight the importance of considering land use, in particular when invoking population growth as a driver of change. They study also suggests that a spatially explicit approach to such projections is important, and that the choice of case studies can influence outcomes. While this study focuses on water supply, we acknowledge that anthropogenic changes of the projected magnitude will have substantial impacts on other aspects of the water and ecological system, and discuss other limitations of the modeling approach.

Kjelson, M. A., P. F. Raquel and F. W. Fisher (1981). Influences of freshwater inflow on chinook salmon (Oncorhynchus tshawytscha) in the Sacramento-San Joaquin Estuary. Proceedings of the National Symposium on Freshwater Inflow to Estuaries. R. D. Cross, and D.L. Williams, U.S. Fish and Wildlife Service. FWS/OBS-81-04: 88-108.
This paper describes present knowledge regarding the influence of freshwater inflow on the surviva1., abundance, migration and rearing jof ·chinook salmon in the upstream (Delta) portion 'of\ the Sacramento-San Joaquin Estuary. Preliminary results indicate that additional inflow at the appropriate time will increase the numbers of fry and Juvenile salmon using the estuary and the survival "of juveniles in the estuary. Results are based on seine and trawl surveys, salmon collections at water diVrrsion fish screens, and mark-recapture techniques. Flow related concerns for salmon in the,estuary stem from 1) water development activities that have altered the distribution of flow resulting in impacts on young and adult migration, and 2) the lack of comprehensive flow standards with which to protect salmon
Future efforts to better quantify salmon flow needs include long term seine and trawl surveys in both the upper and lower portions, of the estuary, as well as intensive, replicated marking experiments done under varied flow conditions and supported by estuarine, ocean and inland recovery programs

Kjelson, M. A., P. F. Raquel and F. W. Fisher. (1982). Life history of fall-run juvenile chinook salmon, Oncorhynchus tshawytscha, in the Sacramento-San Joaquin estuary, California. Estuarine comparisons. V. S. Kennedy. New York, NY, Academic Press: 393-411.

Kjelson, M. A., S. Greene, and P.L. Brandes (1989). A model for estimating mortality and survival of fall-run chinook salmon smolts in the Sacramento River Delta between Sacramento and Chipps Island. Stockton (CA), U.S. Fish and Wildlife Service.

Kjelson, M. A., and P.L. Brandes (1989). The use of smolt survival estimates to quantify the effects of habitat changes on salmonid stocks in the Sacramento- San Joaquin Rivers, California. Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks. C. Levings, L. Holtby and M. Henderson, Canadian Special Publication of Fisheries and Aquatic Sciences 105. 105: 100-115.
Mark-recapture studies of smolt survival in the Sacramento-San Joaquin Delta of California provides empirical data on the effects of water development on fall-run chinook salmon (Oncorhynchus tshawytscha). Recoveries of coded-wire tagged hatchery fish from the ocean troll fishery and estuarine trawling yielded two survival measures that were positively correlated (r = 0.90). Smolt survival from both measures were highly correlated to river flow, temperature, and percent

diversion. Survival of fish exposed to diversion was about 50% less than those not exposed. Study designs to quantify the independent effects of temperature on survival and the survival of wild smolts are presented.

Survival results are being used to evaluate estuarine flow standard governing state and federal water project operations and other salmon protective measures. Regressions of survival and flow applied to simulated historical flows at varied levels of water development indicated estuarine survival has decreased a minimum of 30% in the past 70 yr. Spawner escapements in the Central Valley are positively correlated to flow during their spring smolt outmigration suggesting that flow alterations in the upstream and estuarine habitats at that time influence adult stock production.

Kjelson, M. A., D. Hood, et al. (1989). Survival of chinook salmon smolts in the Sacramento River Delta during 1989, U.S. Fish and Wildlife Service Fisheries Assistance Office, Stockton, Report WQCP-USFWS-2.

Kjelson, M. A. and P. F. Raquel (1981). "The life history of fall run juvenile chinook salmon, Oncorhynchus tshawytscha , in the Sacramento-San Joaquin Estuary of California." Estuaries 4(3).
Juvenile salmon studies emphasize the significance of estuarine rearing, analysis of water development project impacts, and identification of salmon water quality and flow needs. Young chinook utilize San Francisco Bay and the upper estuary (Delta) for both rearing and seaward migration. Trawl and seine surveys indicate that major recruitment of fry (30 to 50 mm) to the estuary begins in January with peak abundance in March. Coded wire nose tags, growth and feeding studies, and routine surveys document rearing between January and June. Growth rate ranges from 0.5 to 1.3 mm per day. Comparisons of estuarine and upstream growth rates are made through scale analysis. The timing and quantity of inflow to the Delta appears to determine the distribution and number of fry reared in the estuary and the survival of smolts. Peak migration of smolts (70 to 80 mm) occurs in May and June. Smolt migration rates range from 8 to 24 km per day. Major food items observed in juvenile chinook vary between the freshwater (cladocera, diptera) and saline (copepods, amphipods, fish larvae) portions of the estuary.

Klamt, R. R., C.M. LeDoux-Bloom, J. Clements, M. Fuller, D. Morse, and M. Scruggs (2002). Gualala River Watershed assessment report. Sacramento, North Coast Watershed Assessment Program, CA Department of Fish and Game: 452 pp.

Kleckner, A., A.R. Stewart, P. Moran, J. Cordell, and J. Toft (2010). Monitoring methylmercury at the base of aquatic food webs: a bottom up, integrated approach for assessing change in mercury bioavailability in nature. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Mercury (Hg) is a naturally occurring trace element in the San Francisco Bay and Delta that has been mobilized by human activities in sufficient quantities such that it poses a threat to fish, wildlife, and humans that consume fish. A significant challenge in addressing the problem in San Francisco Bay has been identifying the relationship among Hg load, biogeochemical transformation to methylmercury (MeHg) and uptake into the base of the food web. Zooplankton have been shown to be particularly sensitive to short term changes in dissolved MeHg concentrations in water and suspended particulate matter within freshwater and more recently marine and estuarine environments. As part of a larger study evaluating Hg dynamics in Sinclair Inlet from August 2008-August 2009, WA, we examined monthly and spatial variability of MeHg concentrations in whole community and species-specific zooplankton samples as well as the MeHg content of their food. Factors thought to influence the bioavailability and uptake of MeHg into the base of the food web were also measured (e.g. chlorophyll a concentrations, TSS, DOC, particulate carbon, particulate nitrogen, and their stable isotopes). A strong seasonal cycle in MeHg in zooplankton was found that corresponded to changes in food quantity and quality. Mean zooplankton MeHg concentrations in the summer and autumn of 2008 from Sinclair Inlet were elevated compared to values in winter. Seasonal variability of

chlorophyll a concentrations ranged from >60 µg/L in summer to <2 µg/L in winter. Further, seasonal variation in zooplankton MeHg corresponded with changes in MeHg in sediments and porewater (reported elsewhere). Monitoring MeHg accumulation in base consumers provides a direct measure of changes in MeHg sources that control accumulation in top predators and thus, could provide a sensitive tool to manage future potential risks associated with climate change, restoration projects, and water management practices in San Francisco Estuary.

Knebel, H. J., T. J. Conomos, et al. (1977). "Clay-mineral variability in the suspended sediments of the San Francisco Bay system, California." Journal of Sedimentary Petrology 47: 229-236.
Semiquantitative determinations of the clay-mineral composition have been made on nearly synoptic samples of surface suspended sediments collected seasonally throughout the San Francisco Bay system. The relative amounts of chlorite + kaolinite are generally highest in the northern reach of the system, whereas illite is dominant in the southern reach. The proportion of montmorillonite is low throughout the bay. Time-series and replicate samples collected at individual stations show that the difference in clay-mineral content between reaches is real and reflects a change in the source of clay-mineral particles within the bay. The Sacramento-San Joaquin river system supplies the northern reach, whereas most clay-mineral particles come from resuspension by waves and tidal currents in the southern reach. Analyses of bottom sediments and the spatial variability in the northern reach suggest that the relationship between the abundance and sources of clay minerals may, in turn, be a function of particle size. This study demonstrates the utility of suspended clay minerals in the interpretation of sediment-dispersal patterns in estuaries.

Knowles, N. (2002). "Natural and management influences on freshwater inflows and salinity in the San Francisco Estuary at monthly to interannual scales." Water Resources Research 38: 1289.
Understanding the processes controlling the physics, chemistry, and biology of the San Francisco Estuary and their relation to climate variability is complicated by the combined influence on freshwater inflows of natural variability and upstream management. To distinguish these influences, alterations of estuarine inflow due to major reservoirs and freshwater pumping in the watershed were inferred from available data. Effects on salinity were estimated by using reconstructed estuarine inflows corresponding to differing levels of impairment to drive a numerical salinity model. Both natural and management inflow and salinity signals show strong interannual variability. Management effects raise salinities during the wet season, with maximum influence in spring. While year-to-year variations in all signals are very large, natural interannual variability can greatly exceed the range of management effects on salinity in the estuary.

Knowles, N. and D. R. Cayan (2002). "Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary." Geophysical Research Letters 29.
California's primary hydrologic system, the San Francisco estuary and its upstream watershed, is vulnerable to the regional hydrologic consequences of projected global climate change. Projected temperature anomalies from a global climate model are used to drive a combined model of watershed hydrology and estuarine dynamics. By 2090, a projected temperature increase of 2.1degreesC results in a loss of about half of the average April snowpack storage, with greatest losses in the northern headwaters. Consequently, spring runoff is reduced by 5.6 km(3) (similar to20% of historical annual runoff), with associated increases in winter flood peaks. The smaller spring flows yield spring/summer salinity increases of up to 9 psu, with larger increases in wet years.

Knowles, N. and D. R. Cayan (2004). "Elevational dependence of projected hydrologic changes in the San Francisco Estuary and watershed." Climatic Change 62(1-3): 319-336.
California's primary hydrologic system, the San Francisco Estuary and its upstream watershed, is vulnerable to the regional hydrologic consequences of projected global climate change. Previous work has shown that a projected warming

would result in a reduction of snowpack storage leading to higher winter and lower spring-summer streamflows and increased spring-summer salinities in the estuary. The present work shows that these hydrologic changes exhibit a strong dependence on elevation, with the greatest loss of snowpack volume in the 1300 - 2700 m elevation range. Exploiting hydrologic and estuarine modeling capabilities to trace water as it moves through the system reveals that the shift of water in mid-elevations of the Sacramento river basin from snowmelt to rainfall runoff is the dominant cause of projected changes in estuarine inflows and salinity. Additionally, although spring-summer losses of estuarine inflows are balanced by winter gains, the losses have a stronger influence on salinity since longer spring-summer residence times allow the inflow changes to accumulate in the estuary. The changes in inflows sourced in the Sacramento River basin in approximately the 1300 - 2200 m elevation range thereby lead to a net increase in estuarine salinity under the projected warming. Such changes would impact ecosystems throughout the watershed and threaten to contaminate much of California's freshwater supply.

Knutson, A. C., Jr., and J.J. Orsi (1983). "Factors regulating abundance and distribution of the shrimp Neomysis mercedis in the Sacramento-San Joaquin Estuary." Transactions of the American Fisheries Society 112: 476-485.
        The mysid shrimp Neomysis mercedis is a major prey of striped bass Morone saxatilis in the inland delta and estuary of the Sacramento and San Joaquin rivers, California. Its abundance during 1968-1981 was highest between 1.2 and 4.6% surface salinity. Cross-delta flow of water to large pumping plants and shallow river channels with high current velocities limited the upstream extent of the shrimp. The population shifted spatially in response to salinity changes caused by variations in river outflow. Annual July to October abundance indexes were highest from 1968 to 1975, and lowest during the drought years 1976 and 1977. Regression analysis showed that population size was negatively related to salinity intrusion and positively related to the abundance of the copepod Eurytemora affinis, an important food item of the shrimp. High N. mercedis populations appear dependent on adequate food supply and minimal salinity intrusion into the western delta.

Knutson, A. C. and J. J. Orsi (1983). "Factors regulating abundance and distribution of the shrimp Neomysis mercedis in the Sacramento-San Joaquin estuary." Transactions of the American Fisheries Society 112: 476-485.

Koehler, C. R. (1995). "California's Bay-Delta Agreement: A model for cooperation." Rivers 5: 46-51.
        In a season of distressing news about environmental protection nationwide, there is a bright spot of progress from California. On 15 December 1994, the federal and state governments signed a document entitled "Principles for Agreement Regarding the Protection of the Bay-Delta Estuary" (Agreement). Signatories included the Secretary of the Interior, Bruce Babbitt; Environmental Protection Agency Administrator, Carol Browner; and California Resources Secretary, Douglas Wheeler. Joining these government officials were about a dozen representatives of California's agricultural, urban, and environmental communities. The Agreement signalled a cease fire in the battle over the Sacramento-San Joaquin Delta (Delta) as the parties negotiated short-term environmental protection measures that allow a long-term solution process to proceed. The Delta is one of the state's primary ecological resources as well as home for endangered fish species and serves double-duty as a major switching yard for some 6-7 million acre-feet of water exported from northern to central and southern California every year. The Agreement is an important example of a private and public partnership that constructively addresses complex ecological and consumptive conflicts over water resources. This article discusses the Bay-Delta dispute and the Agreement as well as the Agreement's potential to serve as a model for other endangered species settlements.

Kohlhorst, D. W. (1976). "Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae." California Fish and Game 62: 32-40.
        To determine the time and location of sturgeon spawning in the Sacramento River, California, sampling was conducted three time per week from March 5 to June 17, 1973 at six locations from the mouth of the Feather River to above Red Bluff. A total of 246 larvae and nine eggs was collected at the mouth of the Feather River,

at river km 180 (river mile 112), and at Colusa. Spawning probably occurred from mid-February to late May, although the majority (93%) was in March and April. Water temperatures during those 2 months ranged from 7.8 to 17.8 C (46 to 64 F). Spawning peaked from April 8 to 17 at a temperature of approximately 14.4 C (58 F). Mean size of larvae increased each month, probably because the growth rate increased with water temperature. Both white sturgeon (Acipenser transmontanus) and green sturgeon (A. medirostris) occur in the Sacramento-San Joaquin Estuary. While the larvae could not be identified, most were probably white sturgeon since that species dominates the Sacramento River sturgeon fishery.

Kohlhorst, D. W. (1980). "Recent trends in the white sturgeon population in California's Sacramento-San Joaquin estuary." California Fish and Game 66: 210-219.

Kohlhorst, D. W., L.W. Botsford, J.S. Brennan, and G.M. Caillet (1991). Aspects of the structure and dynamics of an exploited central California population of white sturgeon (Acipenser transmontanus). Acipenser. P. Williott. Bordeaux, France, Cemagref Publishers: 277-293.

Life history and population dynamics of white sturgeon (Acipenser transmontanus) in central California have been studied intermittently since the sport fishery was reopened in 1954 after being closed since 1917. Recent increases in exploitation rate suggest that further restrictions on the sport fishery are needed to reduce catch and protect spawning stock.

Kohlhorst, D. W. (1999). "Status of striped bass in the Sacramento-San Joaquin Estuary." California Fish and Game 85(1): 31-36.

Kohlhorst, D. W., L. W. Miller, et al. (1980). "Age and growth of white sturgeon collected in the Sacramento-San Joaquin Estuary, California: 1965-1970 and 1973-1976." California Fish and Game 66: 83-95.

Ages of white sturgeon, Acipenser transmontanus, collected in the Sacramento-San Joaquin Estuary from 1965 to 1970 and from 1973 to 1976 were estimated from transverse sections of pectoral fin rays. Sturgeon were difficult to age and estimates of male and female growth rates were not significantly different. A von Bertalanffy growth curve was calculated for ages 0-21 from the 1973-1976 collection. A length-weight relationship was estimated from 1965-1970 data. Estimated growth rate was similar in 1965-1970 and 1973-1976, but was lower than in 1954. It was not possible to determine if a recent decrease in growth rate was real or was due to different aging techniques. Possible causes of reduced growth are discussed.

Kondolf, G. M., J.C. Vick, and T.M. Ramirez (1996). "Salmon spawning habitat rehabilitation on the Merced River, California: An evaluation of project planning and performance." Transactions of the American Fisheries Society 125(6): 899-912.

From 1986 to 1995, over US$2.5 million has been spent or allocated for projects to modify channel conditions to improve spawning habitat for Chinook salmon Oncorhynchus tshawytscha in the Merced, Tuolumne, and Stanislaus rivers, tributaries to the San Joaquin River, California. We evaluated the planning, design and performance of the Riffle 1 B reconstruction on the Merced River. This is typical of the nine individual riffle reconstructions completed to date, involving excavation of the existing channel bed (here, to 0.6 m) and back-filling with smaller gravels believed to be more suitable for salmon spawning. We reviewed project documents, interviewed agency staff, and conducted field surveys to document channel conditions in 1994 for comparison with the project as constructed in 1990. The project planning and design did not consider the site's geomorphic context nor processes of erosion and sediment transport under the current flow regime. As a consequence, spawning-sized gravel placed in the channel was scoured and transported through the site at a flow with a return period of 1.5 years. The need for spawning habitat enhancement in the Merced River is questionable, but if such projects are to be built, we recommend that the project planning and design consider the site's geomorphic context and acknowledge the need for and provide funds for project maintenance, and that the performance of completed projects be systematically monitored and evaluated.

Kondolf, G. M. (1997). "Hungry water: Effects of dams and gravel mining on river channels." Environmental Management 21(4): 533-551.
Rivers transport sediment from eroding uplands to depositional areas near sea level. ii the continuity of sediment transport is interrupted by dams or removal of sediment from the channel by gravel mining, the flow may become sediment-starved (hungry water) and prone to erode the channel bed and banks, producing channel incision (downcutting), coarsening of bed material, and loss of spawning gravels for salmon and trout (as smaller gravels are transported without replacement from upstream). Gravel is artificially added to the River Rhine to prevent further incision and to many other rivers in attempts to restore spawning habitat. It is possible to pass incoming sediment through some smalt reservoirs, thereby maintaining the continuity of sediment transport through the system. Damming and mining have reduced sediment delivery from rivers to many coastal areas, leading to accelerated beach erosion. Sand and gravel are mined for construction aggregate from river channel and floodplains. In-channel mining commonly causes incision, which may propagate up- and downstream of the mine, undermining bridges, inducing channel instability, and lowering alluvial water tables. Floodplain gravel pits have the potential to become wildlife habitat upon reclamation, but may be captured by the active channel and thereby become instream pits. Management of sand and gravel in rivers must be done on a regional basis, restoring the continuity of sediment transport where possible and encouraging alternatives to river-derived aggregate sources.

Kondolf, G. M. (2000). "Some suggested guidelines for geomorphic aspects of anadromous salmonid habitat restoration proposals." Restoration Ecology 8(1): 48-56.
Proposals to improve fish habitat for anadromous salmonids by modifying channel form or substrate must be justified based on geomorphology as well as biology, because geomorphic factors often cause such projects to fail. Proposals should address the geomorphic setting at the watershed scale, by specifying changes in flow regime or sediment yield through tools such as a sediment budget. Proposals should also address geomorphic setting and process at the reach scale, indicating the basis for design channel form and dimensions, calculating the frequency of bed mobilization, and assessing existing gravel quality for spawning habitat enhancement projects. Proposals should include explicit provisions for post-project performance evaluation, including adequate baseline data to permit project-induced changes to be quantified. Restoration projects also require clear objectives and adequate funding for long-term monitoring, and generally would benefit from an adaptive management approach to implementation and evaluation.

Kondolf, G. M., P. Angermeier, et al. (2008). "Projecting Cumulative Benefits of Multiple River Restoration Projects: An Example From the Sacramento-San Joaquin River System in California." Environmental Management 42: 933-945.
Despite increasingly large investments in North America, the potential ecological effects of river restoration programs are still small compared to the degree of human alterations to physical and ecological function. Thus, it is rarely possible to ‘restore’ pre-disturbance conditions; rather restoration programs (even large, well-funded ones) will nearly always involve multiple small projects, each of which can make some modest change to selected ecosystem processes and habitats. At present, such projects are typically selected based on their attributes as individual projects (e.g., consistency with programmatic goals of the funders, scientific soundness, and acceptance by local communities), and ease of implementation. Projects are rarely prioritized (at least explicitly) based on how they will cumulatively affect ecosystem function over coming decades. Such projections require an understanding of the form of the restoration response curve, or at least that we assume some plausible relations and estimate cumulative effects based thereon. Drawing on our experience with the CALFED Bay Delta Ecosystem Restoration Program in California, we consider potential cumulative system-wide benefits of a restoration activity extensively implemented in the region: isolating/filling abandoned floodplain gravel pits captured by rivers to reduce predation of outmigrating juvenile salmon by exotic warmwater species inhabiting the pits. We present a simple spreadsheet model to show how different assumptions about gravel pit bathymetry and predator behavior would affect the cumulative benefits of multiple pit-filling and isolation projects, and how these insights could help

managers prioritize which pits to fill.

Kope, R. G. (1987). "Separable virtual population analysis of pacific salmon with application to marked chinook salmon, Oncorhynchus tshawytscha,." Canadian Journal of Fisheries and Aquatic Sciences 44: 1213-1220.

Kope, R. G. and L. W. Botsford (1990). "Determination of Factors Affecting Recruitment of Chinook Salmon Oncorhynchus tshawytscha in Central California." Fishery Bulletin 88(2): 257-269.

We computed correlations between various population estimates for Central California chinook salmon Oncorhynchus tshawytscha and both freshwater and marine environmental variables using methods that account for intraseries correlation in a more accurate and conservative way than those used previously. These indicated a negative influence of ENSO (El Nino-Southern Oscillation) conditions in the year during which most of these fish are caught or leave the ocean to spawn. Although freshwater environmental influences have been previously proposed on the basis of correlation analysis, and have been demonstrated using direct survival estimates based on marked fish, they were not detectable using correlation techniques that accurately account for intraseries correlation. To further describe oceanographic influences we computed the principal components of upwelling index, sea level height, and sea surface temperature. The first principle component, which reflected the effects of ENSO conditions in the equatorial Pacific during the previous winter, was significantly correlated with chinook salmon abundance in their final year, and marginally correlated with abundance during the first ocean summer.

Koseff, J. R., J.K. Holen, S.G. Monismith, and J.E. Cloern (1993). "Coupled effects of vertical mixing and benthic grazing on phytoplankton populations in shallow, turbid estuaries." Journal of Marine Research 51(4): 843-868.

Coastal ocean waters tend to have very different patterns of phytoplankton biomass variability from the open ocean, and the connections between physical variability and phytoplankton bloom dynamics are less well established for these shallow systems. Predictions of biological responses to physical variability in these environments is inherently difficult because the recurrent seasonal patterns of mixing are complicatcd by aperiodic fluctuations in river discharge and the high-frequency components of tidal variability. We might expect, then, less predictable and more complex bloom dynamics in these shallow coastal systems compared with the open ocean. Given this complex and dynamic physical environment, ca n we develop a quantitative framework to define the physical regimes necessary for bloom inception, and can we identify the importani mechanisms of physical-biological coupling that lead to the initiation and termination of blooms in estuaries and shallow coastal waters? Numerical modeling provides one approach to address these questions. Here we present results of simulation experiments with a refined version of Cloern's (1991) model in which mixing processes are treated more realistically to reflect the dynamic nature of turbulence generation in estuaries. We investigated several simple models for the turbulent mixing coeflicient. We found that the addition of diurnal tidal variation to Cloern's model greatly reduces biomass growth indicating that variations of mixing on the time scale of hours are crucial. Furthermore, we found that for conditions representative of South San Francisco Bay, numerical simulations only allowed for bloom development when the water column was stratified and when minimal mixing was prescribed in the upper layer. Stratification, however, itself is not sufficient to ensure that a bloom will develop: minimal wind stirring is a further prerequisite to bloom development in shallow turbid estuaries with abundant populations of benthic suspension feeders.

Kost, A. L. B. and A. W. Knight (1975). "The food of Neomysis mercedis Holmes in the Sacramento-San Joaquin Estuary." California Fish and Game 61: 35-46.

Gut contents were determined in approx 1500 opossum shrimp (N.mercedis) from the Sacramento-San Joaquin Estuary. The shrimp, obtained from 12 stations over a 13-month period, were 2 to 17 mm (0.08 to 0.67 in) long. The most abundant items in the gut were detritus and diatoms. The percentage of detritus relative to diatoms was greater in winter than in summer, and increased with shrimp size. 40 kinds of diatom were found in the gut. Certain diatom genera predominated in shrimp from particular locations and in shrimp collected during particular times of the yr.

Animal fragments and other items also encountered were much less abundant than detritus and diatoms. Thus, the shrimp appears to eat a variety of food items.

Kramer-Wilt, E., J. Toft, and C.A. Simenstad (2010). BREACH III: Response of benthic macroinvertebrates and insects to vegetation colonization and geomorphic changes at Liberty Island, a restoring wetland in the Sacramento River Delta. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

BREACH III is an interdisciplinary research program that is analyzing the predicted benefits and pitfalls of wetland restoration at Liberty Island in the Sacramento River Delta. Liberty Island was unintentionally inundated in 1998, and presents a unique opportunity because the majority of the island is unvegetated or in early stages of vegetation recolonization and tidal channel development. In addition, it is situated at the base of the Yolo Bypass and Cache Slough complex and receives sediments, nutrients and organic matter from these floodplain areas as well as the potential for native and listed fish species to migrate into Liberty Island. This project aims to identify the critical thresholds that trigger revegetation and geomorphic changes and associated return of emergent marsh invertebrate and nekton fauna as well as potential pitfalls such as wind-wave erosion on intact surrounding levees. Benthic macroinvertebrates and insects are being sampled at six sites in Liberty Island, spanning exposed and protected conditions at the leading edge of freshwater tidal marsh colonization. Sampling is focused on the three main intertidal strata, being conducted within tule vegetation, at the tule edge, and in mudlfats at the leading edge of the vegetation. This analysis represents the emerging resuls of our Spring 2010 investigations. As the site develops, having information on invertebrates associated with each of these main strata will be relevant to Bay-Delta management in assessing the function of specific features in a restoring wetland. Emerging results with comparison between invertebrate sampling of insects, zooplankton, and fish diets will provide the basis for food web level analysis, including multiple stable isotope analysis of food web sources, that can be related to and modeled relative to restoring marsh landscape changes. Process-based integration of the complete BREACH III dataset is aimed towards detailing the transitions between vegetation and mudflats, different types of vegetation, and areas that are more exposed to wind and erosion versus protected. Having this level of analysis within one large developing site should be invaluable for future restoration planning in the Bay-Delta.

Kramer-Wilt, E., and C.A. Simenstad (2010). Habitat associations and macrobenthos interactions of the non-native, invasive Asian clam, Corbicula fluminea, at Liberty Island, a restoring freshwater tidal marsh, Sacramento River delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Initial changes in restoring tidal wetlands are characterized by physical disturbance. While the intent and assumption is that native species will colonize and dominate the new area, non-native species also take advantage of this disturbance after the tidal barriers have been removed. These non-native, invasive species could send restoration sites along different trajectories than originally intended, especially if the actions alter the development of indigenous biota. Changes in landscape and differences in abiotic and biotic factors can affect the ability of non-indigenous, invasive species to colonize an area. Non-native bivalves have been shown to change community structure and ecosystem processes in the areas they invade in ways perceived to be both beneficial and detrimental. The non-native Asian clam, Corbicula fluminea, has been shown to have a variety of effects on estuarine communities including altering zooplankton assemblages, changing organic matter cycling, improving water clarity, and altering benthic invertebrate assemblage structure, among others. C. fluminea has invaded at a restoring freshwater tidal marsh, Liberty Island, in the Sacramento Delta. My research investigates the habitat associations of C. fluminea, comparing the abundances of the clam within different zones of the marsh (vegetation, mudflat, channel) that will inform us about the pattern and rates of C. fluminea colonization as restoring tidal marshes become revegetated under different situations. In addition, we have examined C. fluminea abundances along a fine scale transect from within vegetation through the prograding edge of the vegetation/mudflat edge A manipulation study was

conducted to determine the growth of C. fluminea in various areas of Liberty Island and marsh zones. Understanding the ecology of C. fluminea will contribute to body of knowledge about this species, hopefully allowing restoration design projects to evaluate the consequences of its invasion and potentially minimize the colonization or dominance of this invasive bivalve in newly restored sites.

Kranck, K. and T. G. Milligan (1992). "Characteristics of suspended particles at an 11-hour anchor station in San Francisco Bay, California." Journal of Geophysical Research. C. Oceans 97(C7): 11373-11382.

Hourly measurements of suspended sediment in situ floc size distributions, constituent grain size distributions, total concentrations, and average particle densities are presented for five depths from an 11-hour anchor station in San Francisco Bay. The flocs formed well-sorted distributions with modal sizes between 100 and 500 mu m, whereas the disaggregated sediment was poorly sorted with about the same volume of material in all size classes and relatively little material coarser than 100 mu m. For both types of size spectra, concentrations at the coarse end of the size distribution fall off rapidly at a size range which varied with bottom shear stress. The settling rates corresponding to the modal floc diameters were generally related to the maximum disaggregated diameters by a square relationship, but turbulence appeared to limit floc size in the coarsest samples. Both the floc and disaggregated grain size vary with total concentration, suggesting that flocs are relatively stable entities which do not change during alternating settling and resuspension.

Kraus, T., B.A. Bergamaschi, P.J. Hernes, C. Kendall, and R. Losee (2010). Do reservoirs improve or exacerbate drinking water quality: The balance between loss of terrestrial derived material and addition of algal derived material in San Luis Reservoir. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Dissolved organic carbon (DOC) is a drinking water constituent of concern because during water treatment a fraction of the DOC pool reacts to form disinfection byproducts (DPBs). To improve the quality of water entering the State Water Project (SWP) and local utilities, there has been considerable focus on identifying management actions that will lower DOC concentrations in the Bay-Delta. However, little is known about the production, transformation and loss of DOC within the SWP itself. We examined changes in both the amount and composition of DOC in San Luis Reservoir, the largest water impoundment of the SWP. While the balance between production and loss determines whether a reservoir is a net sink or source of DOC, changes in chemical composition are also important as such changes affects DOC reactivity with respect to DBP formation. Despite only moderate variation in bulk DOC concentration (3.0-3.6 mg C/L), changes in DOM composition indicate that terrestrial derived material entering the reservoir from the Delta was being degraded and replaced by algal derived DOM produced within the reservoir. There were periods when the reservoir was a net source of DOC due to the predominance of algal production (summer), a period when it was a net sink due to the predominance of degradation (fall/winter), and a period when there was a net balance between production and consumption (spring). Substantial changes in the propensity of the DOM pool to form THMs and HAAs illustrate that the DBP precursor pool was not directly coupled to bulk DOC concentration. Results suggest reservoirs which store water derived from the Delta have the potential to attenuate both DOM amount and reactivity with respect to DBP precursors via degradative processes. However, these benefits can be negated, particularly during summer months, by the production of algal derived DOM.

Kress, E., A. Parker, F. Wilkerson, and A. Mueller-Solger (2010). Nutrient loading effects on phytoplankton community structure and biomass in the Sacramento and San Joaquin Rivers. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Nutrient loading from Municipal Waste Water Treatment Plants (WWTP) represent the major source of total nutrient load in the northern San Francisco Estuary (SFE) Delta. The Sacramento Regional WWTP releases ammonium (NH4) to the Sacramento River after secondary treatment while the Stockton WWTP releases nitrate (NO3) to the San Joaquin River after advanced secondary treatment. This contrast in

WWTP effluent type in the Sacramento and San Joaquin Rivers provides a natural experiment to test the hypothesis that shifts in phytoplankton community composition will occur as a result of the inorganic nitrogen species present in the environment. Anthropogenic NH4 appears to influence primary production, particularly that of diatoms, by modulating their physiology, reducing access to NO3, and reducing carbon and nitrogen uptake. In contrast, NO3 has been shown to support faster growth rates by diatoms. This study aims to directly link phytoplankton community shifts with the presence of NH4 by assessing if and how community structure varies with the different types of effluent-DIN that influence the Sacramento and San Joaquin River ecosystems. Data was collected in spring at 35 stations upstream and downstream of each WWTP with samples analyzed for inorganic nutrient concentration, extracted chlorophyll-a, flow cytometry, bbe Fluoroprobe and microscope counts. This study is timely and relevant as food limitation is one potential cause of the pelagic organism decline in the northern SFE Delta and changes in WWTP operations may offer a management tool for restoring productive estuarine foodwebs.

Kristof, R. (1980). The role of physical modeling in the mathematical modeling of the Sacramento-San Joaquin Delta. Estuarine and wetland processes. P. Hamilton and K. MacDonald. New York, Plenum: 285-297.
The Sacramento-San Joaquin Delta is an estuary located at the confluence of the Sacramento and San Joaquin Rivers. Its roughly triangular shape is defined by the principal tributary rivers flowing in at two corners of the triangle and out at the third corner towards San Francisco Bay and the Pacific Ocean. The ultimate objective of this research is to develop a two-dimensional unsteady model of the hydrodynamics and salinity variation of the entire Bay and Delta physical model. The purpose of trying to model the model is that the geometry and boundary conditions are well defined or relatively easily measured; whereas there are a number of unknowns and uncertainties in the prototype values. Thus, this research will not be concerned with how well the physical model simulates the prototype, but will actually consider the physical model as the prototype. It is expected that this approach will allow the emphasis to be placed on the mathematics and provide a distinction between inadequacies of the mathematics and inadequacies in knowledge of the prototype. When completed, the model will provide a much needed tool that can be used to supplement the physical model when time or money constraints make use of the physical model impractical or to enhance the physical model testing by providing a relatively inexpensive means of testing the hypothesis to be examined.

Krone, R. B. (1979). Sedimentation in the San Francisco Bay system. San Francisco Bay: the Urbanized Estuary. T. J. Conomos. California, Pacific Division, American Association for the Advancement of Science: 85-95.

Krone, R. B. (1996). Recent sedimentation in the San Francisco Bay system. San Francisco Bay: The Ecosystem. J. T. Hollibaugh. San Francisco, AAAS: 36-67.

Kuivila, K. (2010). Current-use pesticides and the Sacramento-San Joaquin Delta. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Kuivila, K. M., and C.G. Foe. (1995). "Concentrations, transport and biological effects of dormant spray pesticides in the San Francisco Estuary, California." Environmental Toxicology and Chemistry 14(7): 1141-1150.
The transport and biological effects of dormant spray pesticides were examined in the San Francisco Estuary, California, by measuring dissolved-pesticide concentrations and estimating toxicity using bioassays at a series of sites in January and February 1993. Distinct pulses of pesticides, including diazinon, methidathion, and chlorpyrifos, were detected in the San Joaquin River in January and February and in the Sacramento River in February following rainfall. The higher pesticide loads in the Sacramento River compared with those in the San Joaquin River can be attributed to the greater amount of rainfall in the Sacramento Valley. The use patterns and water solubility of the pesticides can account for the observed temporal and spatial distributions in the two rivers. The pesticide pulses detected at Sacramento were followed through the northern embayment of San Francisco Estuary. In contrast, the pesticide distribution in the Sacramento-San Joaquin Delta changed

from distinct pulses to steady increases in concentration over time. Seven-day bioassays indicated that Sacramento River water at Rio Vista was acutely toxic to Ceriodaphnia dubia (water flea) for 3 consecutive d and San Joaquin River water at Vernalis for 12 consecutive d. These water samples all had the highest diazinon concentrations. Examination of 96-h LC50 values (lethal concentration that kills 50% of test organisms in 96 H) indicates that measured diazinon concentrations could account for most but not all the observed toxicity. Other pesticides present could contribute to the toxicity.

Kuivila, K. M. and B. E. Jennings (2007). "Input, flux, and persistence of six select pesticides in San Francisco Bay." International Journal of Environmental and Analytical Chemistry 87(13-14): 897-911.
Temporal patterns of pesticide inputs to San Francisco Bay were identified and correlated with timing of application and transport mechanism. Fluxes were calculated from measured concentrations and estimated flow. Persistence of the pesticides under typical riverine or estuarine conditions were estimated from laboratory experiments. Simazine was detected most frequently and had the highest flux into the Bay, which could be explained by its continuous use and long half-life. In comparison, diazinon was detected at lower concentrations and had a lower flux which corresponded to its lower use and shorter half-life. The order-of-magnitude lower fluxes of carbofuran and methidathion corresponded to their lower use and expected hydrolysis. Molinate was detected at the highest concentration but its flux was lower than expected, considering its very high use and persistence in the laboratory experiments. Additional loss of molinate is likely to occur from volatilization and photodegradation on the rice fields. Although thiobencarb had the second highest use, it had the lowest flux of the six pesticides, which can be attributed to its loss via hydrolysis, photodegradation, volatilization, and sorption to sediments. Fluxes into San Francisco Bay were equal to or greater than those reported for other estuaries, except for the Gulf of Mexico.

Kuivila, K. M. and G. E. Moon (2004). Potential Exposure of Larval and Juvenile Delta Smelt to Dissolved Pesticides in the Sacramento-San Joaquin Delta, California. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 229-241.
The San Francisco Estuary is critical habitat for delta smelt Hypomesus transpacificus, a fish whose abundance has declined greatly since 1983 and is now listed as threatened. In addition, the estuary receives drainage from the Central Valley, an urban and agricultural region with intense and diverse pesticide usage. One possible factor of the delta smelt population decline is pesticide toxicity during vulnerable larval and juvenile stages, but pesticide concentrations are not well characterized in delta smelt spawning and nursery habitat. The objective of this study was to estimate the potential exposure of delta smelt during their early life stages to dissolved pesticides. For 3 years (1998-2000), water samples from the Sacramento-San Joaquin Delta were collected during April-June in coordination with the California Department of Fish and Game's delta smelt early life stage monitoring program. Samples were analyzed for pesticides using solid-phase extraction and gas chromatography/mass spectrometry. Water samples contained multiple pesticides, ranging from 2 to 14 pesticides in each sample. In both 1999 and 2000, elevated concentrations of pesticides overlapped in time and space with peak densities of larval and juvenile delta smelt. In contrast, high spring outflows in 1998 transported delta smelt away from the pesticide sampling sites so that exposure could not be estimated. During 2 years, larval and juvenile delta smelt were potentially exposed to a complex mixture of pesticides for a minimum of 2-3 weeks. Although the measured concentrations were well below short-term (96-h) LC50 values for individual pesticides, the combination of multiple pesticides and lengthy exposure duration could potentially have lethal or sublethal effects on delta smelt, especially during early larval development.

Kurth, R., and M.L. Nobriga (2001). Food habits of larval splittail. IEP Newsletter. 14: 40-42.

Kuwabara, J. S., C.C.Y. Chang, J.E. Cloern, T.L. Fries, J.A. Davis, and S.N. Luoma (1989). "Trace metal associations in the water column of South San Francisco Bay, California." Estuarine, Coastal and Shelf Science 28(3): 307-325.
Spatial distributions of copper (Cu), zinc (Zn) and cadmium (Cd) were followed along a longitudinal gradient of dissolved organic carbon (DOC) in South San Francisco Bay (herein referred to as the South Bay). Dissolved Cu, Zn and Cd concentrations ranged from 24 to 66 nM, from 20 to 107 nM and from 1·2 to 4·7 nM, respectively, in samples collected on five dates beginning with the spring phytoplankton bloom and continuing through summer,1985. Dissolved Cu and Zn concentrations varied indirectly with salinity and directly with DOC concentration which ranged from 2·1 to 4·1 mg l–1. Available thermodynamic data strongly support the hypothesis that Cu speciation may be dominated by association with dissolved organic matter. Analogous control of Zn speciation by organic complexation was, however, not indicated in our computations. Computed free ion activity estimates for Cu, Zn and Cd were of the order of 10–10, 10–8 and 10–10 M, respectively. The availability of these metals may be among the factors regulating the growth of certain phytoplankton species within this region of the estuary. In contrast to dissolved Cu, dissolved Cd was directly related to the concentration of suspended particulate matter, suggesting a source of dissolved Cd coincident with elevated particle concentrations in the South Bay (e.g. runoff and solute desorption). Consistent with work in other estuaries, partitioning of all three trace metals onto suspended particulates was negatively correlated with salinity and positively correlated with increases in particulate organic carbon associated with the phytoplankton bloom. These results for the South Bay indicate that sorption processes influence dissolved concentrations of these trace metals, the degree of this influence varies among metals, and processes controlling metal distribution in this estuary appear to be more element-specific than spatially- or temporally-specific.

Kuwabara, J. S., C.C.Y. Chang, A. I. Khechfe, and Y.R. Hunter (1996). Importance of dissolved sulfides and organic substances in controlling the chemical speciation of heavy metals in San Francisco Bay. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science AAAS: 157-172.
Describes the chemical processes that control bioavailability of metals like copper in San Francisco Bay. Documents how sulfides in sediments (as well as dissolved organic substances) play a role in controlling speciation of copper in San Francisco Bay.Presents initial benthic flux (release of copper from sediments) measurement for dissolved copper.

Kuwabara, J. S. and G. W. Luther (1993). "Dissolved sulfides in the oxic water column of San Francisco Bay, California." Estuaries 16(3A): 567-573.
Trace contaminants enter major estuaries such as San Francisco Bay from a variety of point and nonpoint sources and may then be repartitioned between solid and aqueous phases or altered in chemical speciation. Chemical speciation affects the bioavailability of metals as well as organic ligands to planktonic and benthic organisms, and the partitioning of these solutes between phases. Our previous work in south San Francisco Bay indicated that sulfide complexation with metals may be of particular importance because of the thermodynamic stability of these complexes. Although the water column of the bay is consistently well-oxygenated and typically unstratified with respect to dissolved oxygen, the kinetics of sulfide oxidation could exert at least transient controls on metal speciation. Our initial data on dissolved sulfides in the main channel of both the northern and southern components of the bay consistently indicate submicromolar concentrations (from <1 nM to 162 nM), as one would expect in an oxidizing environment. However, chemical speciation calculations over the range of observed sulfide concentrations indicate that these trace concentrations in the bay water column can markedly affect chemical speciation of ecologically significant trace metals such as cadmium, copper, and zinc.

Lacy, J., A. Brand, A. Collignon, and M. Stacey (2010). Suspended-sediment flux in the shallows of South San Francisco Bay. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The shallows of San Francisco Bay retain fine sediments, and are thought to

serve as a source of sediments for intertidal mudflats and marshes. Thus sediment transport in the shallows and shoal-channel exchange are important components of the Bay sediment budget. We evaluated near-bed suspended-sediment flux (SSF) at two sites in the eastern shallows of South San Francisco Bay from February 24 to March 16 (spring) and September 9 to October 6, 2009 (fall). The sites were 0.3 km (ShN) and 1.3 km (Be) from the channel edge, at depths of 2.6 m and 2.2 m MLLW. During both deployments and at both sites, the along-channel component of SSF was directed down-estuary during calm periods and up-estuary during windy periods. The up-estuary flux was produced by a correlation of higher suspended-sediment concentration (SSC) with flood tides, due to enhanced wind-wave resuspension at low water and vertical mixing by the ensuing flood-tide currents. SSF during two intense wind events at the end of the fall deployment (wave heights > 0.5 m) was an order of magnitude greater than at any other time during the study. As a result, cumulative flux in fall was directed up-estuary, whereas in spring it was down-estuary and much lower in magnitude. Cumulative cross-shore SSF in the spring was directed toward the channel at ShN, but was toward shore and lower in magnitude at Be. During the fall, cross-channel SSF was directed toward the channel at both sites and was greater at ShN than Be, although the total magnitude of cumulative SSF was much lower at ShN than Be. The spatial variation in cross-channel SSF during both deployments indicates net erosion and transport into the channel, and suggests that the region of the shoals adjacent to the channel does not supply sediment to adjacent marshes.

Lacy, J. R., M. T. Stacey, et al. (2003). "Interaction of lateral baroclinic forcing and turbulence in an estuary." Journal of Geophysical Research. C. Oceans 108(C3).
Observations of density and velocity in a channel in northern San Francisco Bay show that the onset of vertical density stratification during flood tides is controlled by the balance between the cross-channel baroclinic pressure gradient and vertical mixing due to turbulence. Profiles of velocity, salinity, temperature, and suspended sediment concentration were measured in transects across Suisun Cutoff, in northern San Francisco Bay, on two days over the 12.5- hour tidal cycle. During flood tides an axial density front developed between fresher water flowing from the shallows of Grizzly Bay into the northern side of Suisun Cutoff and saltier water flowing up the channel. North of the front, transverse currents were driven by the lateral salinity gradient, with a top-to- bottom velocity difference greater than 30 cm/s. South of the front, the secondary circulation was weak, and along-channel velocities were greater than to the north. The gradient Richardson number shows that stratification was stable north of the front, while the water column was turbulently mixed south of the front. Time-series measurements of velocity and salinity demonstrate that the front develops during each tidal cycle. In estuaries, longitudinal dynamics predict less stratification during flood than ebb tides. These data show that stratification can develop during flood tides due to a lateral baroclinic pressure gradient in estuaries with complex bathymetry.

Langer, M. and D. J. Long (1994). "Association of benthic foraminifera with a gammarid amphipod on tidal flats of San Francisco Bay, California." Journal of Coastal Research 10(4): 877-883.
The gammarid amphipod Oligochinus lighti Barnard is an abundant and conspicuous component of the intertidal benthic fauna in San Francisco Bay, California. This crustacean lives protected in an agglutinated tube, feeding mainly on diatoms and smaller metazoans. Five foraminiferal species were observed as epizoans either attached or free-living at the outer surface of the host's tube. The epizoic association of benthic foraminifera with a filter-feeding invertebrate is considered advantageous in terms of access to increased trophic resources, provision of otherwise limited hard substrates, and possibly shelter. Host selection, benefits and constraints of foraminifera/invertebrate associations are reviewed briefly.

Largier, J. L. (1996). Hydrodynamic exchange between San Francisco Bay and the ocean: the role of ocean circulation and stratification. San Francisco Bay: The Ecosystem. J. T. Hollibaugh. San Francisco, AAAS: 69-104.

Larsen, E. (2010). Meander bend characteristics 1904-2007 on the upper Sacramento River. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Patterns of river channel meander bends and migration were measured between 1904 and 2007 on a 160 km meandering alluvial reach of the Sacramento River by intersecting a sequential set of river channel centerlines mapped from a field survey and aerial photography. Single bends with sinuosity greater than 1.1 were identified. These bends possessed the following characteristics: an average sinuosity of 1.26, an average radius of curvature of 1520 m, an average entrance angle of 43 degrees, an average exit angle of 43 degrees, and an average wave length of 2070 m. The channel length, channel sinuosity, radius of curvature, and entrance and exit angles all decreased over the 103 year period. Wavelength did not change significantly. The average rate of lateral channel change was measured and spatial and temporal patterns were explored. The meander bends have tended to change their average shape over time and tended to be less curved. The decreasing trend may be due in part to the influence of land-use changes, such as the conversion of riparian forest to agriculture, on the “erodibility” of bank and floodplain materials. These metrics provide a quantifiable measure that can be incorporated in a “scorecard” of river health.

Latta, M., and W.J. Kimmerer (2010). Getting to the bottom of it: Planning for subtidal habitats in San Francisco Bay. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Tidal estuaries are intricately linked to the Ocean and Delta and provide numerous ecosystem services that both contribute to and impact overall ecosystem health. Subtidal habitats are fully submerged areas that are intrinsically connected to mudflats, wetlands, creeks, and uplands. Human uses such as fishing, marinas, shipping and ports, dredging, sand mining, transportation projects, recreational use, and industrial uses have direct impacts on the subtidal habitat of the Bay. This “hidden underbelly of the bay” is often considered to be a featureless mud bottom in our urbanized estuary. Despite multiple anthropogenic alterations to the estuarine floor, the bottom of the bay still includes a suite of unique habitats that provide diverse three-dimensional structure including: sand waves more than three meters high; eelgrass and shellfish beds that act as ecosystem engineers and provide reproductive substrate and food resources for species such as herring and salmon; rocky outcrops covered in seaweeds and invertebrates; and the mixed sediments in shoals and channel banks utilized by a variety of species. The San Francisco Bay Subtidal Habitat Goals Project will establish a comprehensive and long-term vision for research, restoration and management of the subtidal habitats of the San Francisco Bay. The Project is a collaborative interagency effort between the Bay Conservation and Development Commission (BCDC), the California Ocean Protection Council/State Coastal Conservancy, National Oceanic and Atmospheric Administration (NOAA), and the San Francisco Estuary Partnership. The Project has created the first set of conceptual models and regional comprehensive GIS maps of subtidal habitats, and specific bold recommendations to protect and sustain subtidal habitats over the next 50 years. This presentation will highlight key recommendations on adaptive management, implementation of future projects, and targeted restoration site opportunities that will be included in the Final San Francisco Bay Subtidal Goals Document and website to be released in November 2010.

Law, P. W. (1994). "A simulation study of salmon carcass survey by capture-recapture method." California Fish and Game 80: 14-28.

Le, K., and A. Chu (2009). Delta Water Project Operations. iEP Newsletter. 22: 2.

Le, K. (2009). Delta Water Project Operations (April through June 2009). IEP Newsletter. 22: 1.

Le, K., and A. Chu (2009). Delta Water Project Operations (January through March 2009). IEP Newsletter. 22: 23.

Le, K., and A. Chu (2009). Delta Water Project Operations Water Year 2008 Annual Summary. IEP Newsletter. 22: 5.

Le, K., and A. Chu (2010). Delta Water Project Operations (January through March 2010). IEP Newsletter. 23: 2.

Lebednik, P., R. Moniz, P. Martos, P.T. Zawislanski, and J. Grattan (2010). Hydrologic fluctuation and oxidation/reduction potential in wetland surficial sediment: Implications for methyl mercury production. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The surficial sediment layer of wetland sediment/soil undergoes marked physico-chemical changes when subjected to short-term (minutes to days) flooding/draining regimes. In particular, oxidation/reduction potential (ORP) manifests large fluctuations as a result of such regimes. While these relationships generally have been understood for some time, knowledge of fine-scale spatio-temporal relationships between ORP values and hydrology has been lacking. Experiments were conducted using intact marsh sediment blocks and their associated biota placed within specially designed mesocosm chambers located at Don Edwards National Wildlife Refuge (NWR) in Fremont, California. These sediment/biota samples were referred to as mesocosm experimental units or MEUs. Each mesocosm chamber was placed within an individual reservoir so that multiple tests could be performed simultaneously and independently. MEUs were instrumented with fixed (for the duration of each experiment) platinum probes that were densely spaced, replicated, and oriented to collect data at 5, 10, and 15 cm below the sediment block surface. Flooding involved the metered introduction into the mesocosm/reservoir of marsh water so that the entire sediment surface was inundated. Draining involved controlled gravity outflow from the mesocosm/reservoir. MEUs were subjected to a variety of tide-simulating flood/drain test patterns as well as instantaneous flood/drain conditions. The results revealed relatively rapid and highly repeatable trends in changes of ORP both temporally and spatially (x, y and z axes). Relevant results from the mesocosm tests were comparable with in situ data from the collection site, indicating that the data from the experimental setup generally were representative of the natural environment. Wetland sediment that exhibits a certain optimal ORP range may be where methyl mercury production is greatest. The potential implications of the effects of marsh hydrology on methyl mercury production and its spatio-temporal variation in sediment will be discussed.

Lebednik, P., L. Paz, J. Grattan, P. Martos, and J. Tallis (2010). Successful restoration of endangered species habitat in Suisun Marsh. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

An 11-acre area in a managed marsh located in the Suisun Marsh was affected by soil remediation activities and alteration of hydrologic structures. The area had been designated as a waterfowl brood pond. Pre-disturbance surveys indicated that a portion of the area was active Salt marsh harvest mouse (SMHM) habitat and provided a basis for establishing the landscape restoration template for the site. SMHM is a federal and State listed endangered species. Removal of biota, extensive soil tilling, soil importation, recontouring and water control improvements resulted in a virgin soil surface, altered topography and a modified hydrologic regime. A key goal of the design effort was to incorporate SMHM habitat and waterfowl brooding functionality into an integrated design that would enhance both ecosystem functions. Complex habitat/topographic modeling was conducted to satisfy the requirement that the project generate habitat values that would be quantitatively equivalent to or greater than pre-existing values. The approach employed for plant recovery was passive (i.e., natural recruitment). The restoration drawings specified elevation precision to ± 0.1 ft and a design that included several waterfowl rearing and loafing islands while incorporating bathymetric configurations that facilitated waterfowl use, predator exclusion, wetland plant recruitment, and ability to control hydrology. Detailed success criteria were established for the restoration project. Construction was conducted in 2007. Several success criteria were met in 2008 and all success criteria were met or exceeded in 2009, two years after construction. Post-construction monitoring included accurately georectified aerial photography and quantitative sampling via a stratified random sampling design. The results demonstrated that restoration was highly successful: wetland plant recruitment occurred precisely within the planned footprint and the biodiversity and cover values were achieved in two years, an unexpectedly short period.

LeDoux-Bloom, B. M. W., M.L. Johnson, S.I. Doroshov, and J.J. Isely (2012). Movement patterns and Site Fidelity of Small Striped Bass in the San Francisco Estuary Watershed. 7th Bienniel Bay-Delta Science Conference, Sacramento Convention Center, 1400 J St., Sacramento, CA.

Small striped bass (n=99; mean fork length= 285 mm) movement and site fidelity within the San
Francisco Estuary watershed were assessed using acoustic telemetry. Ninety-nine fish were
surgically implanted with acoustic transmitters in June and July 2010 and tracked via stationary
receiver (n=300) through October 31, 2011. Fish were tagged on the American (n=11), Sacramento (n=22), and San Joaquin rivers (n=33), the Sacramento Ship Channel (n=15), and
Three Mile Slough (n=18).

A common feature was their progressive migration from rivers and sloughs into bays during
summer and from bays to sloughs and rivers in the late fall and winter. On average, fish moved
greater distances in early summer and early fall. Tidal surfing frequently occurred between the
lower and upper sections of San Pablo Strait in summer and Carquinez Strait in the fall and
winter. Tidal surfing also occurred between shoals and channels (Kimball Island and Antioch).
Preliminary analyses indicate that fish repeatedly select the same migratory routes regardless
of season. Route selection was correlated with tidal movement and appears related to flow
conditions. Movement timing appears related to schooling behavior. Fish stationed at or near
specific locations usually arrived and departed at similar times.

LeDoux-Bloom, C. M., T.R. Sommer, and M.L. Johnson (2010). Suture assessment and surgical recovery of sub-adult striped bass implanted with acoustic transmitters. IEP 2010 Annual Workshop and the 6th Biennial Bay-Delta Science Conference. Poster paper presented at the California State University, Sacramento and the Sacramento Convention Center, Sacramento, CA.

Telemetry coupled with intra-peritoneal implantation of acoustic transmitters has become a valuable tool in fisheries research. Due to the high costs of transmitters, it is imperative to select effective suture material for the species, developmental stage, and the physical and chemical properties of the surrounding water. However, few papers address appropriate suture material and most migration studies do not recapture fish, eliminating the possibility of obtaining information about suture success, incision healing rates, and tag retention. As part of an upcoming acoustic telemetry study in the Bay-Delta, we assessed suture material performance on sub-adult striped bass. After surgically implantation of dummy transmitters into the posterior peritoneal cavity, we monitored suture performance, recovery, survival, and growth weekly over a month long post-operative period. We also examined transmitter retention rates of four treatment and control groups as this age class had not been previously implanted with transmitters. Performance differed among the suture types. Surgi-Loc dissolved (70%) by 7d. Monocryl* Plus and Vicryl* Plus were present at 30d, but the Vicryl* Plus had begun to absorb.Transmitter retention was equal between No Suture and Surgi-Loc (70%) and Monocryl* Plus and Vicryl* Plus (90%) at 30d. Surgery time was fastest for Surgi-Loc and equal between Monocryl* Plus and Vicryl* Plus. Surgery recoveries were similar. Not suturing slowed incision healing and increased ulceration. Vicryl* Plus showed less inflammation and ulceration, and greater incision closure than Monocryl* Plus by 30d. All fish grew. No Suture and Surgi-Loc groups lost weight while the Monocryl* Plus and Vicryl* Plus gained. Internal tissue health and transmitter encapsulation and were greatest when sutures were used. Initial analyses indicate that braided Vicryl*Plus is the best suture material. This study provided important background for the telemetry study which is investigating the presence and migration patterns of sub-adult striped bass in the Bay-Delta.

LeDoux-Bloom, C. M. (2012). Distribution, habitat use, and movement patterns of sub-adult striped bass (Morone saxatilis) in the San Francisco Estuary Watershed, California. Department of Animal Science. Davis, CA, Univerisity of California, Davis. PhD.
- Anesthetic and surgical techniques to implant acoustic transmitters into fishes.
- Spatiotemporal temperature and salinity habitat use by sub-adult striped bass.
- Seasonal movement patterns of sub-adult striped bass.

LeDoux-Bloom, C. M., M.L. Johnson, S.I. Duroshov, and J.J. Isely (2012). Seasonal distribution and habitat usage of juvenile striped bass in the San Francisco Estuary Watershed. 7th Biennial Bay-Delta Science Conference, Sacramento Convention Center, 1400 J St. Sacramento, CA.
Several long term studies document the behavior of adult striped bass (Morone saxatilis)
inhabiting the San Francisco Estuary Watershed, however, comparatively little is known about
the distribution or pelagic habitat use of juveniles (<2 year olds). Understanding juvenile striped
bass behavior can help to illuminate predator-prey interactions and guide restoration planning.
To investigate seasonal distribution and pelagic habitat usage, juvenile striped bass (n=99;
mean fork length= 285 mm) were surgically implanted with acoustic transmitters in June and
July 2010 and tracked via stationary receivers (n=300) through October 31, 2011. Juveniles
were tagged on the American (n=11), Sacramento (n=22), and San Joaquin rivers (n=33), the
Sacramento Ship Channel (n=15), and Three Mile Slough (n=18). We have detections for 82% of
the tagged fish totaling over one million records. Both distribution and pelagic habitat usage
differed significantly between season and tagging locations. Juveniles tagged at sites within the
Estuary had similar seasonal distribution patterns, while those tagged in the American River
exhibited extended freshwater residency. Juveniles were distributed more closely to their tag
site location or made more visits to the area than to other locations except San Pablo Bay. As
day length increased, the distribution of juveniles tagged at estuarine sites shifted toward
warmer (20ºC) and higher salinity (>5 ppt) waters in the west Delta and San Pablo Bay,
respectively. As day length decreased, distribution shifted away from the San Pablo and Central
bays and into Carquinez Strait, Central Delta, and North Delta. During the second summer,
several fish migrated over 200 Km upstream into the Sacramento and Feather rivers. Habitat
usage was dominated in warm (>20ºC), fresh and temperate (10-20 ºC) polyhaline waters in
summer, temperate, fresh and euhaline in fall, temperate mesohaline and fresh over winter,
and temperate fresh and oligohaline habitat during spring.

Lee, B. G., W. G. Wallace, et al. (1998). "Uptake and loss kinetics of Cd, Cr and Zn in the bivalves Potamocorbula amurensis and Macoma balthica: Effects of size and salinity." Marine Ecology Progress Series 175: 177-189.

Radiotracer studies were employed to quantitatively compare the biokinetics of uptake from the dissolved phase (influx rates) and loss (efflux) between 2 bivalves, Potamocorbula amurensis and Macoma balthica, and among the metals Cd, Cr and Zn. Effects of salinity on influx rate were evaluated in these 2 highly euryhaline species as were effects of animal size on uptake and loss. Metal speciation and biological attributes interacted to differentiate bioaccumulation processes among metals and between species. Influx rates of the 3 metals (mu g/g [dry wt]/d) increased linearly with dissolved metal concentrations. Influx rates of Zn in both clams were 3 to 4 x those for Cd and 15 x those for Cr. However, influx on the basis of free ion activities would be faster for Cd than for Zn. Relative influx rates among the metals were similar in the 2 bivalves. But, absolute influx rates of all 3 metals were 4 to 5x greater in P. amurensis than in M. balthica, probably because of differences in biological attributes (i.e. clearance rate or gill surface area). As salinity was reduced from 30 to 5 psu, the influx rate of Cd for P. amurensis increased 4-fold and that for M. balthica increased 6-fold, consistent with expected changes in speciation. However the influx rates of Cr in both clams also increased 2.4-fold over the same range, indicating a biological contribution to the salinity effect. Influx rates of Zn were not significantly affected by salinity. Weight specific metal influx rates (mu g/g [dry wt]/d) were negatively correlated with the tissue dry weight of the clams, but most rate constants determining physiological turnover of assimilated metals were not affected by clam size. The exception was the rate constant for Cd loss, which resulted in faster turnover in large M. balthica than in smaller clams. The rate constant of loss for P. amurensis increased in the order of Cd (0.011/d) < Zn (0.027/d) < Cr (0.048/d). This was different from the hierarchy of rate constants for M. balthica: Zn (0.012/d) < Cd (0.018/d) < Cr (0.024/d).

Lee, B.-G., S. B. Griscom, et al. (2000). "Influences of dietary uptake and reactive sulfides on metal bioavailability from aquatic sediments." Science 5451: 282-284.
Understanding how animals are exposed to the large repository of metal pollutants in aquatic sediments is complicated and is important in regulatory decisions. Experiments with four types of invertebrates showed that feeding behavior and dietary uptake control bioaccumulation of cadmium, silver, nickel, and zinc. Metal concentrations in animal tissue correlated with metal concentrations extracted from sediments, but not with metal in porewater, across a range of reactive sulfide concentrations, from 0.5 to 30 micromoles per gram. These results contradict the notion that metal bioavailability in sediments is controlled by geochemical equilibration of metals between porewater and reactive sulfides, a proposed basis for regulatory criteria for metals.

Lee, B.-G., J.-S. Lee, et al. (2006). "Comparison of selenium bioaccumulation in the clams Corbicula fluminea and Potamocorbula amurensis: A bioenergetic modeling approach." Environmental Toxicology and Chemistry 25: 1933-1940.

Lee, B.-G. and S. N. Luoma (1998). "Influence of microalgal biomass on absorption efficiency of Cd, Cr, and Zn by two bivalves from San Francisco Bay." Limnology and Oceanography 43(7): 1455-1466.
The bioavailability to clams (Potamocorbula amurensis and Macoma balthica) of Cd, Cr, and Zn from suspended particulate material (SPM) collected during a phytoplankton bloom was compared to bioavailability from SPM dominated by resuspended sediments. Bioavailability was also compared among mudflat sediments amended with different levels of living benthic microalgae. Bioavailability was defined by absorption efficiencies determined using pulse chase protocols, modified for studying natural particle assemblages. The partitioning of Cd and Zn to particles (K sub(d)) increased as the microalgae biomass (Chl a) increased in the particle assemblages; partitioning of Cr was less affected by the algal biomass. The clams fed particle assemblages enriched with microalgae absorbed Cd and Zn with significantly greater efficiency than did the clams fed algae-poor particles. This was partially explained by the greater occurrence of Cd and Zn in the cytosolic fraction of the particle assemblages that were microalgae enriched, as well as by the efficient absorption of cytosolic material by the clams. Among metals, Zn was most efficiently absorbed by both clams, and Cr the least. M. balthica absorbed Zn more efficiently from all types of food particles (39-82%) than did P. amurensis

(13-50%). P. amurensis absorbed Cd with greater efficiency from the bloom SPM (44-48%) than did M. balthica (13-21%), but the two clams absorbed Cd similarly from benthic microalgae (26-51%). The addition of microalgae to complex natural particle assemblages clearly affected the bioavailability of associated metals, so studies using sediments (or suspended particulate material) that do not include a realistic living food component could underestimate metal bioavailability from particle ingestion.

Lee, C. E. (2000). "Global phylogeography of a cryptic copepod species complex and reproductive isolation between genetically proximate "populations"." Evolution 54(6): 2014-2027.
The copepod Eurytemora affinis has a broad geographic range within the Northern Hemisphere, inhabiting coastal regions of North America, Asia, and Europe. A phylogenetic approach was used to determine levels of genetic differentiation among populations of this species, and interpopulation crosses were performed to determine reproductive compatibility. DNA sequences from two mitochondrial genes, large subunit (16S) rRNA (450 bp) and cytochrome oxidase I (COI, 652 bp), were obtained from 38 populations spanning most of the species range and from two congeneric species, E. americana and E. herdmani. Phylogenetic analysis revealed a polytomy of highly divergent clades with maximum sequence divergences of 10% in 16S rRNA and 19% in COI. A power test (difference of a proportion) revealed that amount of sequence data collected was sufficient for resolving speciation events occurring at intervals greater than 300,000 years, but insufficient for determining whether speciation events were approximately simultaneous. Geographic and genetic distances were not correlated (Mantel's test; r = 0.023, P = 0.25), suggesting that populations had not differentiated through gradual isolation by distance. At finer spatial scales, there was almost no sharing of mtDNA haplotypes among proximate populations, indicating little genetic exchange even between nearby sites. Interpopulation crosses demonstrated reproductive incompatibility among genetically distinct populations, including those that were sympatric. Most notably, two geographically distant (4000 km) but genetically proximate (0.96% 16S, 0.15% COI) populations exhibited asymmetric reproductive isolation at the F sub(2) generation. Large genetic divergences and reproductive isolation indicate that the morphologically conservative E. affinis constitutes a sibling species complex. Reproductive isolation between genetically proximate populations underscores the importance of using multiple measures to examine patterns of speciation.

Lee, G. F., and A. Jones-Lee (2010). Review of the potential benefits of controlling phosphorus discharges in mud and salt sloughs on SJR/Delta water quality. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The San Joaquin River (SJR) at Vernalis experiences excessive growths of planktonic algae. Those algae cause significant water quality problems in the SJR, SJR Deep Water Ship Channel, and South Delta channels as they die, decay, and deplete oxygen (DO) resources in those waters. The low DO conditions adversely affect aquatic life related beneficial uses of the SJR and Delta. The results of studies by C. Foe, which have been subsequently confirmed by Stringfellow et al., show that Mud and Salt Soughs (MSS) are the primary sources of the phosphorus loads to the SJR at Vernalis and to the South Delta that support excessive growth of phytoplankton in the SJR and South Delta. The total P and soluble ortho P concentrations in the SJR at Vernalis are a few tenths of mg/L P, well-above algal-growth-rate-limiting concentrations, a condition that may cause some to question the efficacy of P load reduction for controlling the excessive algae. However, studies conducted in the Sacramento River/Delta and the Rhine River (by Van Nieuwenhuyse) and in other waterbodies around the world (by Lee and Jones-Lee) document and quantify how reducing the P loads concentration sufficiently, even when there is surplus P in the water, results in significant reduction in phytoplankton biomass. The Central Valley Regional Water Quality Control Board (CVRWQCB) recently gave the managers of agricultural activities in MMS watersheds 10 years in which to develop a management program for the excessive discharges of selenium to the SJR. Since controlling selenium discharges from agricultural lands in those watersheds may concomitantly reduce the P discharges to MMS, it is recommended that the selenium control program be expanded to include evaluation of the reduction of P

loads from those sloughs to the SJR and of the impact of the reduction of P loads on phytoplankton biomass in the SJR at Vernalis. The addition of alum to waterbodies has been widely used to convert algal-available P to unavailable forms for the controlling excessive algae in waterbodies. As part of his service as the PI for the CALFED-support SJR DWSC low-DO TMDL project, G. F. Lee suggested that special-purpose studies be conducted in the MMS watershed to evaluate the feasibility of adding alum to tile drain discharges in the MMS and its efficacy for immobilizing available phosphorus, rendering it unavailable, and thereby reducing the total algal available P load to the SJR. Studies should be undertaken to examine this approach as a means of controlling phytoplankton growth in the SJR. In addition to discussing these issues, this presentation would provide guidance on developing studies to control the excessive growths of phytoplankton in the SJR and South Delta. Additional information on these issues is available on the Lee and Jones-Lee website, www.gfredlee.com in the “Excessive Fertilization” and the Watershed Studies, SJR Watershed Program Delta sections.

Lee, H. (2010). Chlorophyll in San Francisco Bay, Water Years 2008 and 2009. IEP Newsletter. 23: 2.

Lee, H., II, B. Thompson, et al. (2003). "Estuarine and scalar patterns of invasion in the soft-bottom benthic communities of the San Francisco Estuary." Biological Invasions 5(1-2): 85-102.

The spatial patterns of nonindigenous species in seven subtidal soft-bottom communities in the San Francisco Estuary were quantified. Sixty nonindigenous species were found out of the 533 taxa enumerated (11%). Patterns of invasion across the communities were evaluated using a suite of invasion metrics based on the abundance or species richness of nonindigenous species. Patterns of invasion along the estuarine gradient varied with the invasion metric used, and the ecological interpretation of the metrics is discussed. Overall, the estuarine transition community located in the estuarine turbidity maximum zone (mean 5 practical salinity unit (psu)), main estuarine community (mean 16 psu), and marine muddy community (mean 28 psu) were more invaded than two fresh-brackish communities (mean <1 psu) and a marine sandy community (mean 27 psu). Nonindigenous species were numerically dominant over much of the Estuary, making up more than 90% of the individuals in two communities. The percentage of the total species composed of nonindigenous species increased at smaller spatial scales: 11% at the estuary (gamma) scale, 21% at the community (alpha) scale, and 42% at the grab (point) scale. Wider spatial distributions of nonindigenous species and a relatively greater percentage of rare native species may have resulted in this pattern. Because of this scale dependency, comparisons among sites need to be made at the same spatial scale. Native species were positively correlated with nonindigenous species in several of the communities, presumably due to similar responses to small-scale differences in habitat quality. The rate of invasion into the soft-bottom communities of the San Francisco Estuary appears to have increased over the last one to two decades and many of the new introductions have become numerically dominant.

Lee, J., N. De Riu, L. Seung-Hyung, S. Bai, and S. Hung (2010). Effects of dietary methylmercury chloride on the growth performances and tissue burdens in juvenile green (Acipenser medirostris) and white sturgeon (A. transmontanus). 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Methylmercury (MeHg) still exists above the US EPA screening values in the San Francisco Bay-Delta, but there is limited information available on the bioaccumulation and toxic effects of dietary MeHg on the native aquatic animals including green and white sturgeon. Triplicate groups of juvenile green and white sturgeon (30 g ± 2) each were exposed to four levels of dietary methylmercury chloride (MeHg; 0, 20, 40, 80 mg Hg/kg diet) for 8 weeks to determine effects of MeHg on growth performances and tissue burdens of Hg in the sturgeons. Mortality, percent body weight increase, feed efficiency, hepatosomatic and gonadosomatic indices, proximate composition of whole body, and Hg tissue burden including whole body, gill, heart, liver, kidney, and white muscle were determined to assess adverse growth effects and bioaccumulations of dietary MeHg in the sturgeons. There were significant increases ($p<0.05$) in mortality, and decreases in percent body weight

increase and feed efficiency in green and white sturgeon fed MeHg diets compared to fish fed the control diet. Mortality and growth reduction of green sturgeon fed MeHg diets exhibited earlier and more severe adverse effects compared to those of white sturgeon. Mercury significantly (p<0.05) accumulated in all tissues in a dose dependant manner regardless of species, and the highest and lowest Hg concentrations were found in the kidney and whole body, respectively, in both species. On the other hand, there was no significant effect (p>0.05) of MeHg on the whole body proximate compositions of both sturgeons, but crude protein and lipid, and energy content of white sturgeon were significantly higher than those of green. In conclusion, higher mortality, lower percent body weight increase, lower whole body crude protein, lipid, and energy content indicated that green sturgeon was more susceptible to dietary MeHg than white sturgeon in our 8-week growth experiment.

Lee, J. M., L. J. Ross, et al. (1993). Integrating environmental toxicology and monitoring in the development and maintenance of a water quality program: California's rice herbicide scenario. Effective and safe waste management. Interfacing sciences and engineering with monitoring and risk analysis. R. L. Jolley and R. G. M. Wang. Boca Raton, FL, Lewis: 211-224.

Lee, J. S., B. G. Lee, et al. (2000). "Influence of acid volatile sulfides and metal concentrations on metal partitioning in contaminated sediments." Environmental Science and Technology 34(21): 4511-4516.
The influence of acid volatile sulfide (AVS) on the partitioning of Cd, Ni, and Zn in porewater (PW) and sediment as reactive metals (SEM, simultaneously extracted metals) was investigated in laboratory microcosms. Two spiking procedures were compared, and the effects of vertical geochemical gradients and infaunal activity were evaluated. Sediments were spiked with a Cd-Ni-Zn mixture (0.06, 3, 7.5 mu mol/g, respectively) containing four levels of AVS (0.5, 7.5, 15, 35 mu mol/g). The results were compared to sediments spiked with four levels of Cd-Ni-Zn mixtures at one AVS concentration (7.5 mu mol/g). A vertical redox gradient was generated in each treatment by an 18-d incubation with an oxidized water column. [AVS] in the surface sediments decreased by 65-95% due to oxidation during incubation; initial [AVS] was maintained at 0.5-7.5 cm depth. PW metal concentrations were correlated with [SEM - AVS] among all data. But PW metal concentrations were variable, causing the distribution coefficient, Kd sub(pw) (the ratio of [SEM] to PW metal concentrations) to vary by 2-3 orders of magnitude at a given [SEM - AVS]. One reason for the variability was that vertical profiles in PW metal concentrations appeared to be influenced by diffusion as well as [SEM - AVS]. The presence of animals appeared to enhance the diffusion of at least Zn. The generalization that PW metal concentrations are controlled by [SEM - AVS] is subject to some important qualifications if vertical gradients are complicated, metal concentrations vary, or equilibration times differ.

Lee, J. S., B. G. Lee, et al. (2001). "Influence of reactive sulfide (AVS) and supplementary food on Ag, Cd and Zn bioaccumulation in the marine polychaete Neanthes arenaceodentata." Marine Ecology Progress Series. 216: 129-140.
A laboratory bioassay determined the relative contribution of various pathways of Ag, Cd and Zn bioaccumulation in the marine polychaete Neanthes arenaceodentata exposed to moderately contaminated sediments. Juvenile worms were exposed for 25 d to experimental sediments containing 5 different reactive sulfide (acid volatile sulfides, AVS) concentrations (1 to 30 mu mol/g), but with constant Ag, Cd, and Zn concentrations of 0.1, 0.1 and 7 mu mol/g, respectively. The sediments were supplemented with contaminated food (TetraMin super(registered)) containing 3 levels of Ag-Cd-Zn (uncontaminated, 1 x or 5 x metal concentrations in the contaminated sediment). The results suggest that bioaccumulation of Ag, Cd and Zn in the worms occurred predominantly from ingestion of contaminated sediments and contaminated supplementary food. AVS or dissolved metals (in porewater and overlying water) had a minor effect on bioaccumulation of the 3 metals in most of the treatments. The contribution to uptake from the dissolved source was most important in the most oxic sediments, with maximum contributions of 8% for Ag, 30% for Cd and 20% for Zn bioaccumulation. Sediment bioassays where uncontaminated supplemental food is added could seriously underestimate metal exposures in an equilibrated system; N. arenaceodentata feeding on uncontaminated food would be exposed to 40-60%

less metal than if the food source was equilibrated (as occurs in nature). Overall, the results show that pathways of metal exposure are dynamically linked in contaminated sediments and shift as external geochemical characteristics and internal biological attributes vary.

Lehman, P. W. (1981). "Comparison of chlorophyll a and carotenoid pigments as predictors of phytoplankton biomass." Marine Biology 65(3): 237-244.
Chlorophyll a concentration was compared with carotenoid concentration as a predictor of seasonal changes in phytoplankton biomass within Bedford Basin, Nova Scotia, Canada (1976–1977). For all seasons, predictions of biomass from different measures of chlorophyll a were poor and were not improved when chlorophyll a was measured accurately by chromatography. Chlorophyll a and a carotenoid (fucoxanthin) were highly correlated and equally good predictors of total biomass, but neither was related to changes in peridinin concentration. Correlations between specific carotenoids and diatom or dinoflagellate biomass indicate that carotenoids may be useful to describe changes in biomass composition. For all pigments measured, predictions of biomass were hampered when large dinoflagellate cells were present, which biased estimates of total cell volume. Regardless of species composition or cell density, dinoflagellate biomass contributed on the average 68% of the total cell volume measured each day compared with only 14% for diatoms and 17% for flagellates, the most abundant taxa.

Lehman, P. W., W. Kuhn Silk, and A. W. Knight (1981). "Protein and nitrate content of Lemna sp. as a function of developmental stage and incubation temperature." Plant Physiology 68(1): 127-132.
Lemna protein per frond and per root increases with developmental stage until plants are at least two generations old. Protein per frond, per root, and per unit dry weight is greater in plants grown at 23.9 C than at 18.3 C. More protein is found in fronds than in roots, and more nitrate occurs in roots than in fronds. Nitrate per root increases with developmental stage and is higher (per root) in plants grown at 23.9 C than in those grown at 18.3 C. The distribution of generations within a growing population is constant for at least eight doubling times. Whether populations multiply slowly at 15.6 C or more rapidly at 23.9 C, fronds which have not yet produced progeny form 62% of the population; fronds which are one generation old form 24% of the population; and fronds which are two generations old form 9% of the population.

Lehman, P. W. (1990). Evaluation of selected biological factors that may have contributed to the drought and post-drought decline in chlorophyll a concentration. Sacramento, Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary. Technical Report 22.

Lehman, P. W. (1990). Time series analyses of biological and environmental variables for Suisun Bay and the Sacramento and San Joaquin Rivers. Proceedings of the sixth annual Pacific Climate (PACLIM) Workshop. Technical Report 23, Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary, Sacramento, CA.

Lehman, P. W., and R. W. Smith. (1991). "Environmental factors associated with phytoplankton succession for the Sacramento-San Joaquin Delta and Suisun Bay Estuary, California." Estuarine, Coastal and Shelf Science 32(2): 105-128.
Principal coordinates analysis and multiple regression analysis were used to determine environmental factors associated with phytoplankton community succession for the Sacramento-San Joaquin Delta and Suisun Bay estuary. Phytoplankton and environmental data were collected semi-monthly between 1975 and 1982 from 15 sampling sites located throughout the Delta and Suisun Bay. The phytoplankton community shifted between 1976 and 1977 to less dense populations dominated by centric diatoms and reduced numbers of greens, flagellates and pennate diatoms. For the spring-summer, the shift in the phytoplankton community was correlated with increased water temperature, wind velocity, orthophosphate concentration and decreased river flow and precipitation. For the fall, phytoplankton community succession was associated with nutrient concentration, and decreased river flow and precipitation. Similar changes in phytoplankton community succession throughout the estuary plus associations between phytoplankton successional patterns and

region-wide environmental factors suggest that changes in phytoplankton community succession between 1976 and 1982 were affected by the 1976 to 1981 El Nino-Southern Oscillation climatic anomaly.

Lehman, P. W. (1991). Influence of climate on environmental factors associated with long-term changes in chlorophyll production for the Sacramento-San Joaquin Delta and Suisun Bay, California. Proceedings of the eighth annual Pacific Climate (PACLIM) Workshop. Technical Report 31, Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary, Sacramento, CA.

Lehman, P. W. (1991). Variable IX: Atmospheric, biological and miscellaneous. Monthly Climatic Time Series Data for the Pacific Ocean and Western Americas. D. R. M. D. R. Cayan, W. D. Nichols and J. S. DiLeo-Stevens Menlo Park, U.S. Geological Survey. Open-File Report 91-92: 339-344.

Lehman, P. W. (1992). "Environmental factors associated with long-term changes in chlorophyll concentration in the Sacramento-San Joaquin Delta and Suisun Bay, California." Estuaries and Coasts 15(3): 335-348.
Long-term changes in chlorophyll concentration were predicted from environmental variables using Box-Jenkins transfer function models for the Sacramento and San Joaquin rivers and Suisun Bay. Data used for the analyses were collected continuously on a semimonthly or monthly basis over the 17-yr period between 1971 and 1987. Groups of highly correlated environmental variables were summarized along three environmental axes using principal component analysis. The first environmental axis summarized river flow and specific conductance. The second environmental axis summarized water transparency and the third environmental axis summarized air and water temperature. Chlorophyll concentration was significantly corss-correlated with environmental axes and individual environmental variables. Transfer function models developed to describe changes in chlorophyll concentration over time were characterized by lag responses and described between 41% and 51% of the data variation. Significant cross-correlations between environmental axes and the California climate index (CA SLP) were used to develop a conceptual model of the link between regional climate and estuarine production.

Lehman, P. W. (1996). Changes in chlorophyll a concentration and phytoplankton community composition with water-year type in the upper San Francisco Bay Estuary. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, Pacific Division of the American Association for the Advancement of Science AAAS: 351-374.

Lehman, P. W. (1996). Water quality conditions in the Sacramento-San Joaquin Delta 1970-1993. Sacramento, CA, CA Department of Water Resources: 124 pp.
This report is a summary of data collected by the Department of Water Resources and the U.S. Bureau of Reclamation during 1970-1993 and represents an extended version of the annual monitoring reports required by Decision 1485. The report provides long-term and seasonal trends in nutrients and other water quality parameters as well as streamflow for the San Joaquin River downstream of Vernalis.

Lehman, P. W. (1997). The influence of climate on phytoplankton in San Francisco Bay Estuary. Proceedings of the thirteenth annual Pacific Climate (PACLIM) Workshop. Technical Report 53, Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary, Sacramento, CA.

Lehman, P. W. (1998). "Phytoplankton Species Composition, Size Structure, and Biomass and Their Possible Effect on Copepod Food Availability in the Low Salinity Zone of the San Francisco Bay Estuary. IEP (Interagency Ecological Program for the Sacramento-San Joaquin Estuary) Technical Report 62." 38.
Tidal day variation of phytoplankton chlorophyll a concentrations, biovolume, cell diameter and species composition differed across the narrow, low salinity zone between 0.6 to 4 ppt and may influence copepod food availability in the San Francisco Bay Estuary. The highest chlorophyll a concentrations (range 3.2-12.3 micrograms/L-1) diatom densities and production rates of >10 micrometer

diameter cells and widest cell diameters (>5 micrometer diameter) occurred at the landward edge of the salinity zone in both April and May. Near optimum preditor/prey rations, prey estimated spherical diameters and high chlorophyll a concentrations suggest these phytoplankton communities provided good food quantity and quality for the most abundant copepods, Eurytemora affinis, Sinocalanus doerii and Psuedodiaptomus forbesi. At the center of the zone, chlorophyll a concentrations and diatom densities and production rates of >10 micrometer diameter cells were lower and cell diameteres were smaller than upstream. Downstream advection at the center of the zone was reduced by accumulation of phytoplankton with depth and tied: maximum chlorophyll a concentrations occurred during spring flood. The lowest chlorophyll a concentrations (1.4-3.6 micrograms/L-1) and consistently high densities (3000-4000 cells/ml -1) of <5 micrometer diameter cells occurred at the seaward edge of the zone, where the green alga, Nannochloris spp. and the bluegreen alga Synechococcus spp. were the most abundant phytoplankton. Low chlorophyll a concentrations, small prey estimated spherical diameter, low production rates of >10 micrometer diameter cellsa and high predator/prey ratios suggested the seaward edge of the zone had poor food for copepodids and adult copepods. Decreased phytoplankton chlorophyll a concentration, species composition and cell diameter across the low salinity zone was probably a function of both increased clam herbivory since the mid-1980s and decreased chlorophyll a concentration, cell diameter and diatom density since the early 1980s.

Lehman, P. W. (2000). "The influence of climate on phytoplankton community biomass in San Francisco Bay Estuary." Limnology and Oceanography 45(3): 580-590.

The distribution of biomass within the phytoplankton community in northern San Francisco Bay Estuary was influenced by environmental conditions resulting from an interdecadal climate regime shift between 1975 and 1993. A decrease in percentage of diatom biovolume characterized the period 1975-1989 and was caused by both a decrease in diatom and an increase in green and bluegreen algae and flagellate species biovolume. Among the diatoms, there was a greater loss of pennate than centric diatoms. The direct role of climate variation on phytoplankton community biovolume was determined using climatically-related environmental variation that was isolated from the total environmental variation using the covariance between a California climate index and a suite of physical and chemical variables and summarized by principal component analysis. Significant correlation between climatically-related environmental variation and phytoplankton species and species group biovolume suggested a link between climate and the distribution of biovolume in the phytoplankton community. Further analysis of the possible mechanisms controlling the association between climatically-related environmental variation and phytoplankton community biovolume confirmed the importance of water temperature, specific conductance, and water transparency to pennate diatom biovolume. Comparison of natural and anthropogenic processes indicated that diatom biovolume at each station was influenced by environmental conditions even though total diatom biovolume in the estuary was strongly influenced by water diversion.

Lehman, P. W. (2000). "Phytoplankton biomass, cell diameter and species composition in the low salinity zone of northern San Francisco Bay Estuary." Estuaries and Coasts 23(2): 216-230.

Phytoplankton chlorophyll a concentration, biovolume, cell diameter, and species composition differed across the narrow, low salinity zone between 0.6‰ to 4‰ and may influence copepod food availability in the northern San Francisco Bay Estuary. The highest chlorophyll a concentrations (range 3.2–12.3 μg l–1), widest cell diameters (>5 μm diam), highest diatom densities and highest production rates of >10 μm diam cells occurred at the landward edge of the salinity zone in April during a strong spring tide and May during a strong neap tide. Near optimum predator/prey ratios, large prey estimated spherical diameters, and high chlorophyll a concentrations suggest these phytoplankton communities provided good food quantity and quality for the most abundant copepods, Eurytemora affinis, Sinocalanus doerrii, and Pseudodiaptomus forbesi. At the center of the zone, chlorophyll a concentrations, diatom densities, and production rates of >10 μm diam cells were lower and cell diameters were smaller than upstream. Downstream transport was accompanied by accumulation of phytoplankton with depth and tide; maximum biomass occurred on spring tide. The lowest chlorophyll a concentrations (1.4–3.6 µg l–1) and consistently high densities (3,000–4,000 cells ml–1) of <5 µm diam cells occurred at the seaward edge of the zone, where the green alga Nannochloris spp. and the bluegreen alga Synechococcus spp. were the most abundant phytoplankton. Low chlorophyll a concentrations and production rates of >10 µm diam cells, small prey estimated spherical diameters, and high predator/prey ratios suggested the seaward edge of the zone had poor phytoplankton food for copepodids and adult copepods. The seaward decrease in phytoplankton chlorophyll a concentration and cell diameter and shift in species composition in the low salinity zone were probably a function of an estuary-wide decrease in chlorophyll a concentration, cell diameter, and diatom density since the early 1980s that was enhanced in the low salinity zone by clam herbivory after 1987.

Lehman, P. W. (2001). The influence of climate on food web production in northern San Francisco Bay. Proceedings of the Pacific Climate (PACLIM) Workshop, Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary, Sacramento, CA.

Lehman, P. W. (2004). "The influence of climate on mechanistic pathways that affect lower food web production in Northern San Francisco Bay estuary." Estuaries and Coasts 27(2): 312-325.
Significant coherence among time series of environmental and biological production variables suggested mechanistic pathways through which climate contributed to the downward shift in estuarine production (biomass) in northern San Francisco Bay estuary, 1975–1993. Climate directly and indirectly affected physical processes in the estuary through precipitation and its subsequent impact on streamflow and physical variables affected by streamflow. Climate also directly influenced air temperature and wind velocity. The influence if climate was evaluated through a climate index based on sea level pressure. A shift in this climate index in the early 1980s coincided with changes in many environmental variables including water transparency, water temperature, wind velocity, and rainfall. These physical changes were accompanied by a decrease in diatom, total zooplankton, and Neomysis mercedis carbon at the base of the food web throughout the estuary. Box-Jenkins time series coherence analysis was used to quantify associations among these physical, chemical, and biological time series for nine regions of the estuary. These associations were used to develop a conceptual model of mechanistic pathways that directly linked food web carbon production to climate. Strong coherence among diatom, zooplankton, and N. mercedis carbon time series suggested climate also had an indirect impact on food web production through trophic cascade. Differing mechanistic pathways among the nine regions of the estuary suggested climate was an important contributor to the spatial variability in total food web production and trophic structure.

Lehman, P. W., J. Sevier, J. Giuliannotti, and M. Johnson (2004). "Sources of oxygen demand in the lower San Joaquin River, California." Estuaries and Coasts 27(3): 405-418.
Dissolved oxygen concentration below 5 mg l-1 has characterized the lower tidal portion of the San Joaquin River downstream of Stockton, California, during the summer and fall for the past four decades. Intensive field research in 2000 and 2001 indicated low dissolved oxygen concentration was restricted to the first 14 km of the river, which was deepened to 12 m for shipping, downstream of Stockton. The persistent low dissolved oxygen concentration in the shipping channel was not caused by physical stratification that prevented aeration from vertical mixing or respiration associated with high phytoplankton biomass. The low dissolved oxygen concentration was primarily caused by nitrification that produced up to 81% of the total oxygen demand. Stepwise multiple regression analysis isolated dissolved ammonia concentration and carbonaceous oxygen demand as the water quality variables most closely associated with the variation in oxygen demand. Between these two sources, dissolved ammonia concentration accounted for 60% of the total variation in oxygen demand compared with a maximum of 30% for carbonaceous oxygen demand. The Stockton wastewater treatment plant and nonpoint sources upstream were direct sources of dissolved ammonia in the channel. A large portion of the dissolved ammonia in the channel was also produced by oxidation of the organic nitrogen load from upstream. The phytoplankton biomass load from upstream primarily produced the

carbonaceous oxygen demand. Mass balance models suggested the relative contribution of the wastewater and nonpoint upstream load to the ammonia concentration in the shipping channel at various residence times was dependent on the cumulative effect of ammonification, composition of the upstream load, and net downstream transport of the daily load.

Lehman, P. W., G. Boyer, C. Hall, S. Waller, and K. Gehrts (2005). "Distribution and toxicity of a new colonial Microcystis aeruginosa bloom in the San Francisco Bay Estuary, California." Hydrobiologia 541(1): 87-99.

The first distribution, biomass and toxicity study of a newly established bloom of the colonial cyanobacteria Microcystis aeruginosa was conducted on October 15, 2003 in the upper San Francisco Bay Estuary. Microcystis aeruginosa was widely distributed throughout 180 km of waterways in the upper San Francisco Bay Estuary from freshwater to brackish water environments and contained hepatotoxic microcystins at all stations. Other cyanobacteria toxins were absent or only present in trace amounts. The composition of the microcystins among stations was similar and dominated by demethyl microcystin-LR followed by microcystin-LR. In situ toxicity computed for the >75 m cell diameter size fraction was well below the 1 g l–1 advisory level set by the World Health Organization for water quality, but the toxicity of the full population is unknown. The toxicity may have been greater earlier in the year when biomass was visibly higher. Toxicity was highest at low water temperature, water transparency and salinity. Microcystins from the bloom entered the food web and were present in both total zooplankton and clam tissue. Initial laboratory feeding tests suggested the cyanobacteria was not consumed by the adult copepod Eurytemora affinis, an important fishery food source in the estuary.

Lehman, P. W. (2007). "The influence of phytoplankton community composition on primary productivity along the riverine to freshwater tidal continuum in the San Joaquin River, California." Estuaries and Coasts 30 (1): 82-93.

Differences in phytoplankton community composition along a riverine to, freshwater tidal continuum was an important factor affecting the primary productivity and quantity of phytoplankton biomass available to the San Francisco Estuary food web downstream. The relative contribution of riverine and freshwater tidal phytoplankton was determined using measurements of primary productivity, respiration, and phytoplankton species composition along a riverine to freshwater tidal gradient in the San Joaquin River, one of two major rivers that flow into, the San Francisco Estuary. Chla-specific net primary productivity was greater in the freshwater tidal habitat and was correlated with both a higher growth efficiency and maximum growth potential compared with the river upstream. Cluster analysis indicated these differences in growth parameters were associated with differences in species composition, with greater percent diatom and green algal species biomass upstream and flagellate biomass downstream. Correlation between the chla specific net productivity and phytoplankton species composition suggested the downstream shift from riverine diatom and green algal species to flagellate species contributed to the seaward increase in net primary productivity. Environmental conditions, such as specific conductance and water transparency, may have influenced primary productivity along the riverine to freshwater tidal continuum through their effect on both species composition and growth rate. Data suggest light was not the sole controlling factor for primary productivity in this highly turbid estuary; phytoplankton growth rate did not increase when riverine plankton communities from low light conditions upstream were exposed to higher light conditions downstream. This study suggests that the availability of phytoplankton biomass to the estuarine food web may be influenced by management of both phytoplankton growth and community composition along the riverine to freshwater tidal continuum.

Lehman, P. W., G. Boyer, M. Satchwell, S. Waller (2008). "The influence of environmental conditions on the seasonal variation of Microcystis cell density and microcystins concentration in San Francisco Estuary " Hydrobiologia 600(1): 187-204.

A bloom of the cyanobacteria Microcystis aeruginosa was sampled over the summer and fall in order to determine if the spatial and temporal patterns in cell density, chlorophyll a (chl a) concentration, total microcystins concentration, and percent microcystins composition varied with environmental conditions in San Francisco Estuary. It was hypothesized that the seasonal variation in Microcystis cell density and microcystin concentration was ecologically important because it could influence the transfer of toxic microcystins into the aquatic food web. Sampling for Microcystis cell density, chl a concentration, total microcystins concentration and a suite of environmental conditions was conducted biweekly at nine stations throughout the freshwater tidal and brackish water regions of the estuary between July and November 2004. Total microcystins in zooplankton and clam tissue was also sampled in August and October. Microcystis cell density, chl a concentration and total microcystins concentration varied by an order of magnitude and peaked during August and September when αB were high. Low streamflow and high water temperature were strongly correlated with the seasonal variation of Microcystis cell density, total microcystins concentration (cell)–1 and total microcystins concentration (chl a)–1 in canonical correlation analyses. Nutrient concentrations and ratios were of secondary importance in the analysis and may be of lesser importance to seasonal variation of the bloom in this nutrient rich estuary. The seasonal variation of Microcystis density and biomass was potentially important for the structure and function of the estuarine aquatic food web, because total microcystins concentration was high at the base of the food web in mesozooplankton, amphipod, clam, and worm tissue during the peak of the bloom.

Lehman, P. W., T.R. Sommer, and L. Rivard (2008). "The influence of floodplain habitat on the quantity of riverine phytoplankton carbon produced during the flood season in San Francisco Estuary." Aquatic Ecology 42: 363-378.

Primary productivity, community respiration, chlorophyll a concentration, phytoplankton species composition, and environmental factors were compared in the Yolo Bypass floodplain and adjacent Sacramento River in order to determine if passage of Sacramento River through floodplain habitat enhanced the quantity and quality of phytoplankton carbon available to the aquatic food web and how primary productivity and phytoplankton species composition in these habitats were affected by environmental conditions during the flood season. Greater net primary productivity of Sacramento River water in the floodplain than the main river channel was associated with more frequent autotrophy and a higher P:R ratio, chlorophyll a concentration, and phytoplankton growth efficiency (αB). Total irradiance and water temperature in the euphotic zone were positively correlated with net primary productivity in winter and early spring but negatively correlated with net primary productivity in the late spring and early summer in the floodplain. In contrast, net primary productivity was correlated with chlorophyll a concentration and streamflow in the Sacramento River. The flood pulse cycle was important for floodplain production because it facilitated the accumulation of chlorophyll a and wide diameter diatom and green algal cells during the drain phase. High chlorophyll a concentration and diatom and green algal biomass enabled the floodplain to export 14–37% of the combined floodplain plus river load of total, diatom and green algal biomass and wide diameter cells to the estuary downstream, even though it had only 3% of the river streamflow. The study suggested the quantity and quality of riverine phytoplankton biomass available to the aquatic food web could be enhanced by passing river water through a floodplain during the flood season.

Lehman, P. W. (2009). Microcystis Bloom 2008. IEP Newsletter. 22: 2.

Lehman, P. W., S. Mayr, L. Young, B. Larsen, and M. Dempsey (2010). BREACH III: Long-term high frequency measurement of phytoplankton carbon flux among ponds in the Liberty Island wetland, CA. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Liberty Island may be an important wetland for production of native fish like delta smelt because it produces phytoplankton carbon needed to support the aquatic food web. Yet little is known about how much carbon it produces. Previous studies suggest the wetland produces phytoplankton carbon in the interior of the wetland, over 90% of the organic material flux in the wetland is controlled tidal dispersion and flux is seasonally variable. The strong influence of tidal dispersion and seasonal variation indicated long-term high frequency measurements were needed to accurately quantify carbon flux in the wetland. This poster describes new research in progress and initial findings for the CALFED Restoration Breech III study that is designed to quantify how much phytoplankton carbon is produced and transferred among three vegetated and open water ponds in the wetland and the associated physical, chemical and nutrient concentrations over a year. Field measurements are currently being collected at multiple stations using a suite of in situ instruments. These include: high frequency chlorophyll a fluorescence, water temperature, specific conductance, pH, dissolved oxygen and turbidity by YSI 6600 water quality sondes; water flow and direction by acoustic dopplers (ADCP); nitrate, soluble phosphate and silica by EnviroTech nutrient monitors; photosynthetically active radiation by LiCOR monitors; and primary productivity indices by phytoflash rapid rate fluorometers.

Lehman, P. W., S. Mayr, L. Mecum, E. Enright (2010). "The freshwater tidal wetland Liberty Island, CA was both a source and sink of inorganic and organic material to the San Francisco Estuary." Aquatic Ecology 44(2): 359-372.

It is hypothesized that perennial freshwater tidal wetland habitat exports inorganic and organic material needed to support the estuarine food web and to create favorable habitat for aquatic organisms in San Francisco Estuary. It is also hypothesized that most of the material flux in this river-dominated region is controlled by river flow. The production and export of material by Liberty Island were measured and compared using discrete monthly and continuous (15 min) measurements of a suite of inorganic and organic materials and flow between 2004 and 2005. Seasonal material flux was estimated from monthly discrete data for inorganic nutrients, suspended solids and salts, organic carbon and nitrogen and phytoplankton and zooplankton group carbon and chlorophyll a and pheophytin pigment. Estimates of material flux from monthly values were compared with measured daily material flux values for chlorophyll a concentration, salt and suspended solids obtained from continuous measurements (15 min) using YSI water quality sondes. Phytoplankton carbon produced within the wetland was estimated by in situ primary productivity. Most inorganic and organic materials were exported from the wetland on an annual basis, but the magnitude and direction varied seasonally. Dissolved inorganic nutrients such as nitrate, soluble phosphorus, total phosphorus and silica as well as total suspended solids were exported in the summer while total and dissolved organic carbon were exported in the winter. Salts like chloride and bromide were exported in the fall. Chlorophyll a and pheophytin were exported in the fall and associated with diatom and cyanobacteria carbon. Mesozooplankton carbon was dominated by calanoid copepods and exported most of the year except summer. Continuous sampling revealed high hourly and daily variation in chlorophyll a, salt and total suspended solids flux due to high frequency changes in concentration and tidal flow. In fact, tidal flow rather than river discharge was responsible for 90% or more of the material flux of the wetland. These studies indicate that freshwater tidal wetlands can be a source of inorganic and organic material but the export of material is highly variable spatially and temporally, varies most closely with tidal flow and requires high frequency measurements of both tidal flow and material concentration for accurate estimates.

Lehman, P. W., L. Liu, A. Tang, and S. Mayr (2010). Hydrologic connectivity was a key factor affecting material flux among vegetated and non-vegetated ponds in the freshwater tidal wetland, Liberty Island, CA. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The export of inorganic and organic material from the freshwater tidal wetland Liberty Island is hypothesized to be important to estuarine fishery production in San Francisco Estuary. However, the mechanisms that control material production and flux among ponds within the wetland are poorly understood. This initial study conducted for a CALFED Restoration Project grant determined the relative contribution of vegetated and open water ponds to material flux of Liberty Island over a tidal day. Material flux was determined from discrete samples of inorganic and organic materials (nitrate, soluble phosphorus, ammonium, salt, suspended sediments, total and dissolved inorganic carbon, dissolved organic nitrogen, chlorophyll a concentration and phytoplankton species composition) collected at 1.5 hr intervals along with continuous flow measurements over the tidal day (25 hr) at input and output locations of three ponds. Concentrations of inorganic and organic materials were 2 times greater in the vegetated ponds which also contributed up to 35% of the inorganic and 45% of the organic material flux in the wetland. The shallow and vegetated Lower Beaver Pond in the interior of the wetland that was hydraulically isolated from the river channel accounted for over 80% of this exported material. Lower Beaver Pond also accounted for 50-60% of the total organic carbon and chlorophyll a flux in the open water pond. Export of this inorganic and organic material from Lower Beaver Pond occurred on ebb tide and was facilitated by small-scale topography and tidal asymmetry that caused a 40% greater material flux on ebb tide. Vegetated ponds contrasted with the open water pond where of the 65-96% inorganic and 61-85% of the organic material in the wetland was stored. This study suggests the importance of vegetated and hydraulically isolated ponds to inorganic and organic material production and export in delta wetland rehabilitation and restoration programs.

Lehman, P. W., S.J. Teh, G.L. Boyer, M.L. Nobriga, E. Bass, C. Hogle (2010). "Initial impacts of Microcystisaeruginosa blooms on the aquatic food web in the San Francisco Estuary." Hydrobiologia 637(1): 229-248.

The impact of the toxic cyanobacterium Microcystisaeruginosa on estuarine food web production in San Francisco Estuary is unknown. It is hypothesized that Microcystis contributed to a recent decline in pelagic organisms directly through its toxicity or indirectly through its impact on the food web after 1999. In order to evaluate this hypothesis, phytoplankton, cyanobacteria, zooplankton, and fish were collected biweekly at stations throughout the estuary in 2005. Concentrations of the tumor-promoting Microcystis toxin, microcystin, were measured in water, plankton, zooplankton, and fish by a protein phosphatase inhibition assay, and fish health was assessed by histopathology. Microcystis abundance was elevated in the surface layer of the western and central delta and reached a maximum of 32 × 109 cells l−1 at Old River in August. Its distribution across the estuary was correlated with a suite of phytoplankton and cyanobacteria species in the surface layer and 1 m depth including Aphanizomenon spp., Aulacoseira granulata, Bacillaria paradoxa, Rhodomonas spp., and Cryptomonas spp. Shifts in the phytoplankton community composition coincided with a decrease in the percentage of diatom and green algal carbon and increase in the percentage of cryptophyte carbon at 1 m depth. Maximum calanoid and cyclopoid copepod carbon coincided with elevated Microcystis abundance, but it was accompanied by a low cladocera to calanoid copepod ratio. Total microcystins were present at all levels of the food web and the greater total microcystins concentration in striped bass than their prey suggested toxins accumulated at higher trophic levels. Histopathology of fish liver tissue suggested the health of two common fish in the estuary, striped bass (Morone saxatilis), and Mississippi silversides (Menidia audens), was impacted by tumor-promoting substances, particularly at stations where total microcystins concentration was elevated. This study suggests that even at low abundance, Microcystis may impact estuarine fishery production through toxic and food web impacts at multiple trophic levels.

Lehman, P. W., F. Mejia, and L. Young (2010). The use of flowCAM technology to quantify real time changes in phytoplankton communities in the delta. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The flowCAM is a digital imaging flow cytometer that can identify live phytoplankton species and quantify cell density and biomass automatically in field water samples. This machine is being used to characterize real time phytoplankton communities within the Sacramento and San Joaquin River on water quality transect studies as a part of a CALFED Science funded study to evaluate the flowCAM technology for use in the estuary. Continuous real time measurements of turbidity, water temperature, dissolved oxygen, chlorophyll a fluorescence, salt and pH from YSI 6600 sondes were paired with real time phytoplankton community identification and cell counts at 10 minute intervals using the flowCAM. These data demonstrated the value of the flowCAM to rapidly quantify shifts in phytoplankton communities such the shifts from cryptophytes in early spring to diatoms in early summer and the associated shift in water temperature and turbidity. The flowCAM was also used to quantify the size structure of the phytoplankton carbon in the estuary. This study confirmed the ability of flowCAM technology to rapidly quantify the quantity and quality of phytoplankton food resources in San Francisco Estuary. Such technology is needed to facilitate rapid response resource management of food web resources.

Lehman, P. W., L. Young and K. Marr (2010). Using FlowCAM technology to characterize Delta plankton. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Lehman, P. W., G. Boyer, et al. (2010). Factors that have influenced the increase of Microcystis blooms in the San Francisco Estuary since 2003. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Blooms of the toxic cyanobacterium Microcystis were first observed in the San Francisco Estuary in 1999. Field studies were conducted between 2003 and 2008 to determine the magnitude, duration and rate of bloom increase over time and the factors affecting bloom development and toxin concentration. Data suggest there has been a 20 to 40 fold increase in Microcystis cell density, chlorophyll a concentration and microcystin toxin concentration in the surface layer of the estuary during the summer between 2003 and 2008. The increase in bloom density was associated with decreased water flow and increased water temperature, water transparency, specific conductance, and nitrogen concentration. The initiation and duration of the bloom was influenced by the presence of water temperature above 20oC, water flow below 36 m3/s, nitrogen to phosphorus molar ratios below 16, total dissolved solids below 500 mg/L and total suspended solids below 10 mg/L. The study confirmed the increase in both magnitude and distribution of Microcystis blooms in the estuary over time and the potential impact of water quality conditions on this increase. Understanding the impact of environmental conditions on Microcystis blooms is an important need for development of management plans under the Bay Delta Conservation Plan (BDCP).

Leidy, R. A., and P.B. Moyle (1998). Conservation status of the world's fish fauna: An overview. Conservation biology for the coming decade. P. L. Fiedler, and P.M. Kareiva. New York, NY, Chapman & Hall: 187-227.

Leidy, R. A., G. Becker, et al. (2005). "Historical status of coho salmon in streams of the urbanized San Francisco Estuary, California." California Fish and Game 91(4): 219-254.
The historical status of coho salmon, Oncorhynchus kisutch, was assessed in 65 watersheds surrounding the San Francisco Estuary, California. We reviewed published literature, unpublished reports, field notes, and specimens housed at museum and university collections and public agency files. In watersheds for which we found historical information for the occurrence of coho salmon, we developed a matrix of five environmental indicators to assess the probability that a stream supported habitat suitable for coho salmon. We found evidence that at least 4 of 65 Estuary watersheds (6%) historically supported coho salmon. A minimum of an additional 11 watersheds (17%) may also have supported coho salmon, but evidence is inconclusive. Coho salmon were last documented from an Estuary stream in the early-to-mid 1980s. Although broadly distributed, the environmental characteristics of streams known historically to contain coho salmon shared several characteristics. In the Estuary, coho salmon typically were members of three-to-six species assemblages of native fishes, including Pacific lamprey, Lampetra tridentata, steelhead, Oncorhynchus mykiss, California roach, Lavinia symmetricus, juvenile Sacramento sucker, Catostomus occidentalis, threespine stickleback, Gasterosteus aculeatus, riffle sculpin, Cottus gulosus, prickly sculpin, Cottus asper, and/or tidewater goby, Eucyclogobius newberryi. We found evidence for the occurrence of coho salmon in eight watersheds characterized by the coast redwood, Sequoia sempervirens, riparian community. These conditions are more typical of the high rainfall coastal streams directly tributary to the Pacific Ocean that historically had relatively high abundances of coho salmon. All streams known or suspected historically to support coho salmon are characterized by cool summer water temperatures, suitable spawning and juvenile rearing habitat, distinct surface water connections to the estuarine and marine environments, as well as stream flows during the months of February through May suitable for smolt out-migration.

Leitritz, E., and R.C. Lewis (1980). "Trout and salmon culture (hatchery methods)." California Department of Fish and Game, Fish Bulletin 164 Fish Bulletin 164.

This volume has been prepared at the request of many of the Department's fish hatchery personnel. A hatchery treatise has long been needed to acquaint the beginning employee with the rudiments of fish culture, and also to act as a handy reference for those already experienced in the work. In addition, it should lead to greater uniformity in operations and to increased hatchery efficiency. It will also be helpful to the growing number of private trout hatchery operators. Even though the art of trout culture dates back to the year 1741, when Stephen Ludwig Jacobi started artificial propagation in Germany, advances in methods and techniques were slow until shortly before World War II. Applied science and mechanics have revolutionized fish hatchery operations. The uses of new chemicals in treating diseases in hatcheries, eradicating undesirable fish populations, spawning, and transporting fish, and the employment of labor-saving devices such as fish loaders, self-graders, incubators, and dry feeds are only a few of the advances illustrating the progress made. In considering literature to be embodied in this volume and suggestions received from Department employees, attention was directed especially to subjects which would benefit the average hatcheryman and assist him with his everyday problems.

Leland, H. V., Scudder, B.C. (1990). "Trace elements in Corbicula fluminea from the San Joaquin River, California." The Science of the Total Environment 97/98: 641-672.

Leland, H. V., and S.V. Fend (1998). "Benthic invertebrate distributions in the San Joaquin River, California, in relation to physical and chemical factors." Canadian Journal of Fisheries and Aquatic Sciences 55(5): 1051-1067.

The invertebrate fauna of nontidal portions of the lower San Joaquin River and its major tributaries is described in relation to water quality and habitat using canonical correspondence analysis, autecological metrics, and indicator species analysis. A large-scale (basin-wide) pattern in community response to salinity (sulfate-bicarbonate type) was detected when standardized, stable substratum was sampled. Community structure, taxa richness, and EPT (ephemeropterans, plecopterans, and trichopterans) richness varied with dissolved solids concentration (55-1700 mg total dissolved solids L-1), and distributions of many taxa indicated salinity optima. Distinct assemblages associated with either high or low salinity were evident over this range. Large-scale patterns in community structure were unrelated to pesticide distributions. Structure and taxa richness of invertebrate assemblages in sand substratum varied both with salinity and with microhabitat heterogeneity. The benthic fauna generally was dominated by a taxa-poor assemblage of specialized psammophilous species, contributing to a weaker relationship between community structure and water quality than was observed using standardized substratum. Habitat types and associated dominant species were characterized using indicator species analysis. Species assemblages did not vary substantially with irrigation regime or river discharge, indicating that structure of invertebrate communities was a conservative measure of water quality.

Leland, H. V., L. R. Brown, et al. (2001). "Distribution of algae in the San Joaquin River, California, in relation to nutrient supply, salinity and other environmental factors." Freshwater Biology 46(9): 1139-1167.

The taxonomic composition and biomass of the phytoplankton and the taxonomic composition of the phytobenthos of the San Joaquin River and its major tributaries were examined in relation to water chemistry, habitat and flow regime. Agricultural drainage and subsurface flow contribute to a complex gradient of salinity and nutrients in this eutrophic, lowland type river. Because of light-limiting conditions for growth, maintenance demands of the algae exceed production during summer and autumn in the San Joaquin River where there is no inflow from tributaries. In contrast to substantial gains in concentration of inorganic nitrogen and soluble reactive phosphorus during the summer of normal-flow years, net losses of algal biomass (2-4 mu g L super(-1) day super(-1) chlorophyll a) occurred in a mid-river segment with no significant tributary inflow. However, downstream of a large tributary draining the Sierra Nevada, a substantial net gain in algal biomass (6-11 mu g L super(-1) day super(-1)) occurred in the summer, but not in the spring (loss of 1-6 mu g L super(-1) day super(-1)) or autumn (loss of 2-5 mu g L super(-1) day super(-1)). The phytoplankton was dominated in summer by r-selected centric diatoms (Thalassiosirales), species both tolerant of variable salinity and widely

distributed in the San Joaquin River. Pennate diatoms were proportionally more abundant (in biomass) in the winter, spring and autumn. Abundant taxa included the diatoms Cyclotella meneghiniana, Skeletonema cf. potamos, Cyclostephanos invisitatus, Thalassiosira weissflogii, Nitzschia acicularis, N. palea and N. reversa, and the chlorophytes Chlamydomonas sp. and Scenesdesmus quadricauda. Patterns in the abundance of species indicated that assembly of the phytoplankton is limited more by light and flow regime than by nutrient supply. The phytobenthos was dominated by larger, more slowly reproducing pennate diatoms. Few of the abundant species are euryhaline. The diatoms Navicula recens and Nitzschia inconspicua and cyanophytes, Oscillatoria spp., were the principal late-summer benthic species upstream in the mainstream and in drainages of the San Joaquin Valley. Many of the other abundant diatoms (Amphora veneta, Bacillaria paxillifer, Navicula symmetrica, Nitzschia amphibia, N. fonticola, N. palea, Pleurosigma salinarum) of late-summer assemblages in these segments also are motile species. While many of these species also were abundant in segments downstream of confluences with rivers draining the Sierra Nevada, the relative abundance of prostrate and erect or stalked diatoms and Stigeoclonium sp. was greater in these lower San Joaquin River segments. A weighted-averaging regression model, based on salinity and benthic-algal abundance in the San Joaquin River and segments of its major tributaries within the San Joaquin Valley, yielded a highly significant coefficient-of-determination (r super(2)=0.84) and low prediction error between salinity inferred from the species and that observed, indicating that salinity tolerance is a primary constraint on growth and assembly of the phytobenthos. The same measures of predictability indicated poor performance of a model based on inorganic nitrogen. However, with a greater representation of tributaries (including segments within the Sierra Nevada foothills) in the sample set, an inorganic nitrogen model also yielded a highly significant coefficient-of-determination (r super(2)=0.87) and low prediction error between the species-inferred and the observed concentration. As with the salinity model (r super(2)=0.94) for the enlarged data set, a systematic difference (increased deviation of residuals) existed at high inorganic nitrogen concentrations. These results indicate substantial interaction between salinity and inorganic nitrogen as constraints on the structure of benthic-algal communities of the San Joaquin River basin.

Lent, M., J. Oram, and L. McKee (2010). Guadalupe River Watershed Model: Support tool for regional Hg and PCB management. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
San Francisco Bay is listed as impaired for mercury (Hg) and PCBs, and the associated TMDLs call for improved regional loads estimates and large load reductions from urbanized small tributaries, including a >90% load reduction from the Guadalupe River watershed. In order to address this call, managers need improved information on which BMPs may be effective and what magnitude of application will be needed to see measurable loads reductions at the watershed and regional scales. To inform the management questions, the Regional Monitoring Program for Water Quality in San Francisco Estuary funded a pilot study to develop a dynamic watershed model of the Guadalupe River Watershed. This watershed offers a unique opportunity to study legacy Hg from the largest-producing former Hg mine in North America as well as legacy PCBs from the manufacturing industries of the 1950s and 1960s. The availability of abundant local data combined with management issues make Guadalupe River Watershed an ideal location to explore the use of models for better understanding transport of contaminants in the urban landscape. The objective of the Guadalupe Watershed Model project is to understand the source, release, and transport of sediment and contaminants from a large mixed land-use, highly urbanized watershed. The first phase of the project was to develop the underlying hydrological model in the EPA’s watershed modeling software suite BASINS/HSPF. A reasonably accurate model (within 20% of annual flow volumes) was developed despite challenges due to the high degree of watershed hydromodification including numerous reservoirs and percolation ponds. The second phase, currently underway, is to add sediment, Hg and PCBs into the model. The final model will serve to improve the accuracy of Hg and PCB load calculations, to investigate inter-annual load variability due to climate, and to allow scenario testing for optimizing management practices.

Lentz, K. (2010). Celebrating 40 years of science excellence: Highlights from the past. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Leopold, L. B., J. N. Collins, et al. (1993). "Hydrology of Some Tidal Channels in Estuarine Marshland near San-Francisco." Catena 20(5): 469-493.
Measurements of velocity, depth, discharge, and slope were simultaneously made at ten gages along a natural estuarine channel 19,000 feet in length in Petaluma Marsh, California. Along the study reach the channel decreases from a width of 47 feet at its mouth to nearly zero at its headward extent, with accompanying decrease in depth. Though gage height varies with time in a smooth sinusoidal manner at all stations, this is not true for velocity, discharge, or slope. Velocity is rather constant for long periods in the ebb cycle and differs but little along the length of the channel. It is somewhat higher on ebb than on flood tide. At most gage sites, velocity continues one-half to one hour after the gage height has reached its maximum or minimum value and reversed. In this channel water surface slope is considerably greater in the midreach of channel than in either the mouthward or headward reaches. Slopes vary from less than .0001 to about .0005 through much of a tidal cycle. At some stages of both ebb and flood, the upper end of the channel has a positive slope while the lower end a negative or adverse slope. At those times the longitudinal profile of water surface is bow shaped or V shaped.

Lesen, A. E. (2005). "Relationship between benthic foraminifera and food resources in South San Francisco Bay, California, USA." Marine Ecology Progress Series 297: 131-145.
Foraminifera are amongst the most abundant known protists found in marine habitats, and are ecologically important constituents of the benthic meiofauna. The seasonality of San Francisco Bay, USA, makes it an ideal system in which to study the relationships between primary production, organic matter fluxes, and food resources for the benthos. Samples were collected at one site at a depth of 8.8 m in South San Francisco Bay on monthly cruises for 2 yr from November 1999 through November 2001. Each month, water column parameters (chlorophyll concentration) and sediment parameters (chlorophyll, total organic carbon, nitrogen, amino acids, bacterial abundance) were measured, and benthic foraminiferal population size and biovolume was counted and calculated. Water column chlorophyll peaked in the spring of 2000 and 2001, and the fall of 2000, with sediment parameters peaking 1 to 3 mo later. The benthic foraminiferal standing crop peaked during the spring of both study years, and showed a large peak in the fall of 2001 dominated by the small-sized foraminifer Fursenkoina pontoni. The data strongly suggest that benthic foraminifera increase in number following phytoplankton blooms when many kinds of sediment organic matter also increase. Foraminiferal biovolume does not necessarily follow this pattern, especially when peaks in standing crop mainly consist of small-sized individuals. Foraminiferal biovolume and standing crop generally increase when the sediment C:N ratio increases, suggesting that benthic foraminiferal populations in South San Francisco Bay may be exploiting a detrital food source in addition to recently deposited fresh phytoplankton. Thus, foraminifera are probably quick to exploit sediment organic matter, and may be important remineralizers of nutrients in this system.

Lesen, A. E. (2006). "Sediment organic matter composition and dynamics in San Francisco Bay, California, USA: Seasonal variation and interactions between water column chlorophyll and the benthos." Estuarine, Coastal and Shelf Science 66(3-4): 501-512.
Sediment and water column data from four sites in North, Central and South San Francisco Bays were collected monthly from November 1999 through November 2001 to investigate the seasonal variation of benthic organic matter and chlorophyll in channel sediments, the composition and quality of sediment organic matter (SOM), and the relationship between seasonal patterns in benthic organic matter and patterns in water column chlorophyll. Water column chlorophyll peaked in the spring of 2000 and 200 1, characteristic of other studies of San Francisco Bay phytoplankton dynamics, however an unusual chlorophyll peak occurred in fall 2000. Cross-correlation analysis revealed that water column chlorophyll at these four channel sites lead sediment parameters by an average of 2 to 3 months. Sediment organic matter levels in the San Francisco Bay channel showed seasonal cycles that followed patterns of

water column production: peaks in water column chlorophyll were followed by later peaks in sediment chlorophyll and organic matter. Cyclical, seasonal variations also occurred in sediment organic matter parameters with sediment total organic carbon (TOC) and total nitrogen (TN) being highest in spring and lowest in winter, and sediment amino acids being highest in spring and summer and lowest in winter. Sediment chlorophyll, total organic carbon. and nitrogen were generally positively correlated with each other. Sediment organic matter levels were lowest in North Bay, intermediate in Central Bay, and highest in South Bay. C:N ratio and the ratio of enzyme hydrolyzable amino acids to TOC (EHAA:TOC) data suggest that SOM quality is more labile in Central and northern South Bay, and more refractory in North Bay and southern South Bay. (c) 2005 Elsevier Ltd. All rights reserved.

Lesmeister , S., C. Teh, I. Flores, M. Kawaguchi, and S.J. Teh (2010). Differences in sensitivity of Eurytemora affinis and Pseudodiaptomus forbesi to chlorpyrifos, permethrin and bifenthrin. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Lesmeister, S., C. Teh, I. Flores, M. Kawaguchi, and S.J. Teh (2010). Evaluation of acute toxicity of chlorpyrifos, permethrin and bifenthrin on the copepods Eurytemora affinis and Pseudodiaptomus forbesi of the San Francisco Estuary. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The calanoid copepods, Eurytemora affinis and Pseudodiaptomus forbesi, are a critical link between primary producers and fish in the San Francisco Estuary (SFE). Since these meso-zooplankton play an important role as food sources to larval fish and pelagic organisms, factors affecting their decrease in recent years warrants investigation. One potential source of decline is exposure to insecticides from agricultural and urban run-off into the SFE. The goal of this study was to determine and contrast the acute effects of three insectides, an organophosphate, Chlorpyrifos, and two pyrethroids, Permethrin and Bifenthrin , to E. affinis and P. forbesi . The 96-hour medial lethal concentration (LC-50) of Chlorpyrifos on E. affinis (803.2ng/L) is more sensitive than P. forbesi(1211.9ng/L). However, P. forbesi is almost two-times more sensitive than E. affinis Permethrin (LC-50 86.0 and 158.1 ng/L, respectively). For Bifenthrin, E. affinis show an LC-50 value of 13.3 ng/L, while values for P. forbesi are currently under investigation. E. affinis show up to a 100-fold increase in sensitivity to pyrethroid insecticides compared to organophosphate insecticides. Additionally, our data indicate that there are species specific differences in response to insecticides. Shifts in types and timing of insecticide use may cause a decline in copepod abundance, and ultimately have a negative impact on the SFE food web. In addition to determining the chronic effects of insecticides to primary consumers, future research should include the influence of abiotic factors, such as temperature, pH and salinity, on the long term effects of the interaction between calanoid copepods and insecticides at the population and community levels.

Levin, L. A., Neira, C., Grosholz, E. D. (2006). "Invasive cordgrass modifies wetland trophic function." Ecology 87(2): 419-432.

Vascular plants strongly control belowground environments in most ecosystems. Invasion by vascular plants in coastal wetlands, and by cordgrasses (Spartina spp.) in particular, are increasing in incidence globally, with dramatic ecosystem-level consequences. We examined the trophic consequences of invasion by a Spartina hybrid (S. alterniflora X S. foliosa) in San Francisco Bay (USA) by documenting differences in biomass and trophic structure of benthic communities between sediments invaded by Spartina and uninvaded sediments. We found the invaded system shifted from an algae-based to a detritus-based food web. We then tested for a relationship between diet and tolerance to invasion, hypothesizing that species that consume Spartina detritus are more likely to inhabit invaded sediments than those that consume surface algae. Infaunal diets were initially examined with natural abundance stable isotope analyses and application of mixing models, but these yielded an ambiguous picture of food sources. Therefore, we conducted isotopic enrichment experiments by providing super(15)N-labeled Spartina detritus both on and below the sediment surface in areas that either contained Spartina or were unvegetated. Capitellid and nereid polychaetes, and oligochaetes, groups shown to

persist following Spartina invasion of San Francisco Bay tidal flats, took up super(15)N from labeled native and invasive Spartina detritus. In contrast, we found that amphipods, bivalves, and other taxa less tolerant to invasion consumed primarily surficial algae, based on super(13)C enrichment experiments. Habitat (Spartina vs. unvegetated patches) and location of detritus (on or within sediments) did not affect super(15)N uptake from detritus. Our investigations support a "trophic shift" model for ecosystem response to wetland plant invasion and preview loss of key trophic support for fishes and migratory birds by shifting dominance to species not widely consumed by species at higher trophic levels.

Levin, S. A. (1989). Challenges in the development of a theory of community and ecosystem structure and function. Perspectives in ecological theory. J. Roughgarden, R. M. May and S. A. Levin. Princeton, NJ, Princeton University Press: 242-255.

Levings, C. D. (1994). Estuarine science and management needed to maintain Pacific salmon production. Changes in fluxes in estuaries: implications from science to management. K. R. Dyer and R. J. Orth. Fredensborg, Denmark, Olsen & Olsen: 417-421.
This paper provides a brief review of the scientific data and management strategies used for maintaining Pacific salmon (Oncorhynchus) habitat in Northeast Pacific estuaries. Estuaries within metropolises (e.g. Vancouver, Seattle, San Francisco) in the area support major commercially significant stocks of salmon. Comprehensive plans involving ecological zoning and guidelines for habitat management and restoration are in place in the urbanized estuaries, but inference is heavily relied on instead of specific data. Managers are using semi-quantitative rating guides to try and achieve 'no net loss of productive capacity' for salmon production. Long-term data sets on estuarine ecosystems are necessary to determine specific habitat factors which affect salmon production, but often scientific sampling programs cannot be maintained at the time scales needed. Integration of scientific research with monitoring and evaluation schemes may be the only way the required data can be obtained. Monitoring should be designed to answer specific hypotheses.

Lewis, J., and K.E. Boyer (2010). Effects of heat waves on the macroinvertebrate community of San Francisco Bay eelgrass (Zostera marina) beds. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The effects of global climate change are expected to include an increase in the frequency and intensity of heat waves. These heat waves have the potential to cause mass mortality in nearshore and estuarine macroinvertebrate populations and differential responses to heat waves among different species are likely to lead to alterations in the assemblage of these communities. Changes in the assemblage of macroinvertebrates in San Francisco Bay eelgrass (Zostera marina) beds have potential to alter both the effects of grazers on the growth of eelgrass and the availability of prey for the fish species that utilize eelgrass beds as a nursery. Changes in metabolic rates caused by long-term increases in temperature also have potential to alter the nutritional requirements of eelgrass-associated macroinvertebrates. This study examines the effects of heat on six macroinvertebrate species commonly found in San Francisco Bay eelgrass beds: Ampithoe valida, Caprella californica, Caprella drepanochir, Corophium alienense, Idotea resecata, and Phyllaplysia taylori. As a preliminary investigation into the effects of heat and heat waves on these species, we placed individuals in a manometric respirometer and measured respiration rates at a series of temperatures to simulate a heat wave event Survival at increasing temperatures was also measured for all species. Increasing temperature had a very strong effect on metabolic rate in all species and per gram metabolic rates were significantly different among species at all temperatures. Some differences in response to simulated heat waves were observed among different species. These responses suggest macroinvertebrate community structure could be altered in San Francisco Bay eelgrass beds as a result of global climate change and that further examination of this change and its implication for eelgrass growth and fish prey availability is warranted.

Li, S. (2010). Achieving the California water supply and Delta ecological improvement simultaneously. 6th Biennial Bay-Delta Science Conference. Workshop

presentation at the Sacramento Convention Center, Sacramento, California.
It is clear that the current CVP system needs to be fixed. The decision on how it is to be fixed is critical to spending billions of dollars wisely. This decision must be made now before Delta levees crumble or before the Delta water supply is exceeded. There is only one alternative that can achieve the stated dual objectives of securing an ample water supply and improving ecological conditions in the Delta. The Sacramento River must be used as the sole water source for water supply and all of the San Joaquin River water must be used to resist salt intrusion during incoming tides. The peripheral canal is needed because sufficient amounts of Sacramento River water are unattainable under the present CVP configuration. There are two mandatory operational conditions that must be kept at all times to avoid continuing adverse ecological effects: 1) No San Joaquin River water can be used for water export because export of that water is the chief factor of Delta ecological degradation, and 2) The present level of outflow to San Francisco Bay shall be maintained because it is already at half its historical levels, would be easy to use as an operational term condition, and is a necessary control to operate Delta water export in a sustainable manner.

Lieberman, D. M., M. J. Horn, et al. (2001). "Effects of a temperature control device on nutrients, POM and plankton in the tailwaters below Shasta Lake, California." Hydrobiologia 452(1-3): 191-202.
A temperature control device (TCD) was installed by the U.S. Bureau of Reclamation on Shasta Dam, California, in March 1997 for controlling downstream river temperatures. Temperature modification was required to aid recovery of the endangered winter run chinook salmon (Oncorhynchus tshawytscha) in the Sacramento River, and to minimize loss of generating capacity as a result of releasing deeper, colder water through low level outlet works to meet downstream temperature criteria. This study began two years prior to operation of the TCD, to compare pre- and post-operational changes on downstream tailwaters, including nutrients, particulate organic matter (POM) and plankton. During epilimnetic withdrawals from January to mid-June, and mid-level withdrawals through August, operation of the TCD was associated with decreases in dissolved nitrate-nitrate concentrations, localized increases in small particulate organic matter (SPOM) at Shasta tailwaters, increases of bacillariophyta (<25 mu m size fraction), and increases in copepod biomass. These changes can potentially influence the food base of the river and therefore fish production in the Upper Sacramento River, including the chinook salmon.

Light, T. and M. P. Marchetti (2007). "Distinguishing between invasions and habitat changes as drivers of diversity loss among California's freshwater fishes." Conservation Biology 21(2): 434-446.
Many of California's native populations of freshwater fish are in serious decline, as are freshwater faunas worldwide. Habitat loss and alteration, hydrologic modification, water pollution, and invasions have been identified as major drivers of these losses. Because these potential causes of decline are frequently correlated, it is difficult to separate direct from indirect effects of each factor and to appropriately rank their importance for conservation action. Recently a few authors have questioned the conservation significance of invasions, suggesting that they are "passengers" rather than "drivers" of ecological change. We compiled an extensive, watershed-level data set of fish Presence and conservation status, land uses, and hydrologic modifications in California and used an information theoretic approach (Akaike's information criterion, AIC) and path analysis to evaluate competing models of native fish declines. Hydrologic modification (impoundments and diversions), invasions, and proportion of developed land were all predictive of the number of extinct and at-risk native fishes in California watersheds in the AIC analysis. Although nonindigenous fish richness was the best single predictor (after native richness) of fishes of conservation concern, the combined ranking of models containing hydrologic modification variables was slightly higher than that of models containing nonindigenous richness. Nevertheless, the path analysis indicated that the effects of both hydrologic modification and development on fishes of conservation concern were largely indirect, through their positive effects on nonindigenous fish richness. The best fitting path model was the driver model, which included no direct effects of abiotic disturbance on native fish declines. Our results suggest that, for California freshwater fishes, invasions are the primary

direct driver of extinctions and population declines, whereas the most damaging effect of habitat alteration is the tendency of altered habitats to support nonindigenous fishes.

Linares-Casenave, J., R. Linville, J. Van Eenennaam, and S. Doroshov (2010). Selenium tissue burden in resident white sturgeon (Acipenser transmontanus) of the San Francisco Bay Delta Estuary. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

High Selenium (Se) loads into the San Francisco Bay-Delta (SFBD) from the agricultural runoff and oil refineries are effectively bioaccumulated and biomagnified in the food webs and can impair reproduction in high trophic level species, such as white sturgeon, via accumulation of Se in the egg yolk. The objective of this study was to determine selenium tissue burden in SFBD resident white sturgeon to assess Se bioaccumulation levels in different organs, including liver and ovaries supporting synthesis and deposition of the egg yolk. We obtained 26 female and 21 male SFBD-resident white sturgeon in 2002 (3), 2003 (20), 2004 (16) and 2005 (8) from California DFG (n=23) and UC Davis on-going field projects (n=24). Size (length and weight), age (fin ray) and reproductive stage of development (light microscopy), and kidney, liver, gonad and muscle selenium concentrations (ICP/AES, Protocol # 8137, California Animal Health and Food Safety Laboratory System, UC Davis) were determined in all fish. Most sturgeon were sub-adults with immature gonads (18 females, 18 males), but 8 females had yolky (vitellogenic) eggs and 3 males had mature spermatozoa. Se concentrations in muscle, gonads and liver significantly increased with fish size, whereas kidney Se was not correlated to body size and was at highest level compared to other organs. There was no difference between sexes in Se concentrations in kidney (12.83   0.51), liver (11.85 1.04) and muscle (7.09 0.52) (pooled data, mean and S.E.M. Se in µg•g Dry Weight, n =47, ANOVA p> 0.05), but Se concentration in the ovary was higher than in testis (p = 0.04). Females with vitellogenic eggs had higher Se concentrations in the ovaries (20.77 ± 4.11 vs. 5.22 ± 2.50), liver (21.84 ± 2.07 vs. 8.03 ± 1.03) and muscle (10.18 ± 1.93 vs. 5.48 ± 0.64), compared with less advanced, previtellogenic females (p<0.05). The elevated Se concentrations in the ovaries and liver of vitellogenic SFBD white sturgeon were comparable with levels previously shown to cause reproductive toxicity in dietary Se experiments with captive white sturgeon.

Lindberg, J. C., G. Tigan, L. Ellison, T. Rettinghouse, M.M. Nagel, and K. M. Fisch (2013). "Aquaculture Methods for a Genetically Managed Population of Endangered Delta Smelt." North American Journal of Aquaculture 75(2): 11.

In response to Federal listing of the Delta Smelt Hypomesus transpacificus as a threatened species in 1993, intensive
fish culture techniques were developed to provide a supply of fish for research activities. The Delta Smelt was listed
as endangered by the state of California in 2009, and several agencies worked quickly to develop a captive refuge
population under genetic management. Captive 2-year-old wild-origin Delta Smelt served as the founding population
in 2008. Each year, 250 genetically selected, single pair crosses are made in vitro, and the resultant full-sibling families
are combined to rear in multifamily groups. Typically, eight families are reared together from egg to adult stage, with
80% or more of the initial families represented at the adult stage. Multifamily rearing provides an efficient way of
achieving a breeding population of 500 in a smaller facility. Juvenile survival increased from 18% in 2009 to 39%
in 2010, as facilities and methodologies improved. Growth rate also increased significantly from 2009 to 2010 (from
0.19 to 0.25 mm/d). Subdermal alphanumeric tags identified individuals and allowed spawning of select individuals
to preserve genetic diversity in the refuge population. Group marking, by adipose fin clip, provided efficiencies in
time and space. Tagging and genetic analyses enabled in vitro spawning of recommended pair crosses each year. At
present, we recommend completing the majority of spawning from February to mid-May

and continuing to augment
the refuge population with wild fish each year. The refuge population provides one type of safeguard against species
extinction and provides an example for endangered fish culture.

Lindemuth, T. (2010). Linking nutrients to severe Delta eutrophication, 2009/2010 findings. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The Problem - The problem we have been examining is the collapse of the Delta food chain, especially in the shallow water zones so critical to supporting plant, insect, and juvenile fish communities. Approach - We have been monitoring water quality and relative benthic invertebrate abundance in the western Delta regions centering on Big Break and nearby aquatic environs. What makes our monitoring programs unusual is on-site sampling and analyses lasting twelve or more hours per day, which is necessary to observe diurnal changes in the water. Findings - Our data show a striking relationship between diurnal cycles in dissolved oxygen and pH to concentrations of nitrates, along with the appearance of specific types of aquatic weeds. These data are being evaluated looking at the benthic zones as an unsteady state bioreactor. Inputs to the bioreactor model are nutrient concentrations, relative sunlight intensity and duration, and presence and density of aquatic vegetation. A key finding is the observation of intense cycling of dissolved oxygen and pH in zones. In these zones, normally abundant phytoplankton cling to plant stems and leaves, effectively lowering the turbidity of the water. This then, allows sunlight to penetrate nearly to the bottom, as much as two meters deep, resulting in phenomenal rates of photosynthesis and companion reactions. Relevance - Our preliminary findings, which are still ongoing, suggest additional measures for Bay-Delta management other than flows within and out of the Delta. Programs that minimize or eliminate nitrate and ammonia discharges to Delta tributaries almost certainly will help. At its simplest could be broad scale education of the public on the benefits of not wasting water and fertilizer to runoff, both at homes and on fields and orchards. Improvement in nutrient removal from treated municipal effluent also needs to be part of the equation.

Lindley, S. T., Mohr, M.S. (2003). "Modeling the effect of striped bass (Morone saxatilis) on the population viability of Sacramento River winter-run chinook salmon (Oncorhynchus tshawytscha)." Fishery Bulletin 101: 321-331.

We estimated the impact of striped bass (Morone saxatilis)pre dation on winter-run chinook salmon (Oncorhynchus tshawytscha)with a Bayesian population dynamics model using striped bass and winter-run chinook salmon population abundance data.Winter-run chinook salmon ex tinction and recovery probabilities under different future striped bass abundance levels were estimated by simulating from the posterior dis tribution of model parameters.The model predicts that if the striped bass population declines to 512,000 adults as expected in the absence of stocking, winter-run chinook salmon will have about a 28%chance of quasi-extinction (de .ned as three consecutive spawning runs of fewer than 200 adults)within 50 years.If stocking stabilizes the striped bass population at 700,000 adults,the predicted quasi-extinction probability is 30%.A more ambitious stocking program that maintains a population of 3 million adult striped bass would increase the predicted quasi-extinction probability to 55%.Extinction prob ability,but not recovery probability,was fairly insensitive to assumptions about density dependence.We conclude that winter-run chinook salmon face a seri ous extinction risk without augmenta tion of the striped bass population and that substantial increases in striped bass abundance could significantly increase the threat to winter-run chi-nook salmon if not mitigated by increas ing winter chinook salmon survival in some other way.

Lindley, S. T., M. S. Mohr, et al. (2000). "Monitoring protocol for Sacramento River winter chinook salmon, Oncorhynchus tshawytscha: application of statistical power analysis to recovery of an endangered species." Fishery Bulletin 98(4): 759-766.

When monitoring endangered species, natural resource managers require a recovery benchmark and a statistical procedure to test whether the benchmark has been met. We applied statistical power analysis to devise such a procedure for the endangered Sacramento River winter chinook salmon (Oncorhynchus tshawytscha). Winter chinook salmon management currently focuses on population growth rate, and our procedure used a Student's t-test to evaluate whether the average population growth rate is significantly lower than the management goal of 0.57 per generation. In the test, the null hypothesis was that the growth rate was not lower than the desired rate. In contrast to the usual hypothesis-testing framework, our procedure did not control for the type-I error rate. Instead, it controlled for the statistical power (the complement of the type-II error rate) and uses the resulting type-I error rate, computed from the sample size and other information, for the test. This procedure is conservative for winter chinook salmon in that, if all assumptions are met, it provides the specified level of assurance of detecting dangerously low population growth rates.

Lindley, S. T., R. S. Schick, et al. (2006). "Historical population structure of Central Valley steelhead and its alteration by dams." San Francisco Estuary and Watershed Science 4(1): [np].

Effective conservation and recovery planning for Central Valley steelhead requires an understanding of historical population structure. We describe the historical structure of the Central Valley steelhead evolutionarily significant unit using a multi-phase modeling approach. In the first phase, we identify stream reaches possibly suitable for steelhead spawning and rearing using a habitat model based on environmental envelopes (stream discharge, gradient, and temperature) that takes a digital elevation model and climate data as inputs. We identified 151 patches of potentially suitable habitat with more than 10 km of stream habitat, with a total of 25,500 km of suitable habitat. We then measured the distances among habitat patches, and clustered together patches within 35 km of each other into 81 distinct habitat patches. Groups of fish using these 81 patches are hypothesized to be (or to have been) independent populations for recovery planning purposes. Consideration of climate and elevation differences among the 81 habitat areas suggests that there are at least four major subdivisions within the Central Valley steelhead ESU that correspond to geographic regions defined by the Sacramento River basin, Suisun Bay area tributaries, San Joaquin tributaries draining the Sierra Nevada, and lower-elevation streams draining to the Buena Vista and Tulare basins, upstream of the San Joaquin River. Of these, it appears that the Sacramento River basin was the main source of steelhead production. Presently, impassable dams block access to 80% of historically available habitat, and block access to all historical spawning habitat for about 38% of the historical populations of steelhead.

Lindley, S. T., R. S. Schick, et al. (2006). "Framework for assessing viability of threatened and endangered Chinook salmon and steelhead in the Sacramento-San Joaquin basin." San Francisco Estuary and Watershed Science IN press.

Protected evolutionarily significant units (ESUs) of salmonids require objective
and measurable criteria for guiding their recovery. In this report, we develop a method
for assessing population viability and two ways to integrate these population-level assessments
into an assessment of ESU viability. Population viability is assessed with quantitative extinction models or criteria relating to population size, population growth
rate, the occurrence of catastrophic declines, and the degree of hatchery influence. ESU viability is assessed by examining the number and distribution of viable populations
across the landscape and their proximity to sources of catastrophic disturbance. Central Valley spring-run and winter-run Chinook salmon ESUs are not currently viable, according to the criteria-based assessment. In both ESUs, extant populations may be at low risk of extinction, but these populations represent a small portion of the historical ESUs, and are vulnerable to catastrophic disturbance. The winter-run Chinook salmon ESU, in the extreme case, is represented by a single population that spawns outside of its historical spawning range. We are unable to assess the status of the Central Valley steelhead ESU with our framework because almost all of its roughly 80 populations are classified as data deficient. The few exceptions are those
populations with a closely associated hatchery, and the naturally-spawning fish in

these
streams are at high risk of extinction. Population monitoring in this ESU is urgently
needed.
Global and regional climate change poses an additional risk to the survival of salmonids
in the Central Valley. A literature review suggests that by 2100, mean summer temperatures in the Central Valley region may increase by 2-8°C, precipitation will likely shift to more rain and less snow, with significant declines in total precipitation
possible, and hydrographs will likely change, especially the the southern Sierra Nevada mountains. Warming at the lower end of the predicted range may allow springrun
Chinook salmon to persist in some streams, while making some currently utilized habitat inhospitable. At the upper end of the range of predicted warming, very little
spring-run Chinook salmon habitat is expected to remain suitable.
In spite of the precarious position of Central Valley salmonid ESUs, there are prospects for greatly improving their viability. Recovering Central Valley ESUs may require re-establishing populations where historical populations have been extirpated
(e.g., upstream of major dams). Such major efforts should be focused on those watersheds
that offer the best possibility of providing suitable habitat in a warmer future.

Linville, R. G., S. N. Luoma, et al. (2002). "Increased selenium threat as a result of invasion of the exotic bivalve Potamocorbula amurensis into the San Francisco Bay-Delta." Aquatic Toxicology 57: 1-2.

Following the aggressive invasion of the bivalve, Potamocorbula amurensis, in the San Francisco Bay-Delta in 1986, selenium contamination in the benthic food web increased. Concentrations in this dominant (exotic) bivalve in North Bay were three times higher in 1995-1997 than in earlier studies, and 1990 concentrations in benthic predators (sturgeon and diving ducks) were also higher than in 1986. The contamination was widespread, varied seasonally and was greater in P. amurensis than in co-occurring and transplanted species. Selenium concentrations in the water column of the Bay were enriched relative to the Sacramento River but were not as high as observed in many contaminated aquatic environments. Total Se concentrations in the dissolved phase never exceeded 0.3 mu g Se per l in 1995 and 1996; Se concentrations on particulate material ranged from 0.5 to 2.0 mu g Se per g dry weight (dw) in the Bay. Nevertheless, concentrations in P. amurensis reached as high as 20 mu g Se per g dw in October 1996. The enriched concentrations in bivalves (6-20 mu g Se per g dw) were widespread throughout North San Francisco Bay in October 1995 and October 1996. Concentrations varied seasonally from 5 to 20 mu g Se per g dw, and were highest during the periods of lowest river inflows and lowest after extended high river inflows. Transplanted bivalves (oysters, mussels or clams) were not effective indicators of either the degree of Se contamination in P. amurensis or the seasonal increases in contamination in the resident benthos. Se is a potent environmental toxin that threatens higher trophic level species because of its reproductive toxicity and efficient food web transfer. Bivalves concentrate selenium effectively because they bioaccumulate the element strongly and lose it slowly; and they are a direct link in the exposure of predaceous benthivore species. Biological invasions of estuaries are increasing worldwide. Changes in ecological structure and function are well known in response to invasions. This study shows that changes in processes such as cycling and effects of contaminants can accompany such invasions.

Liu, F., C. Hunsaker, and R.C. Bales (2012). "Controls of streamflow generation in small catchments across the snow-rain transition in the Southern Sierra Nevada, California." Hydrological Processes: 14.

Processes controlling streamflow generation were determined using geochemical tracers for water years 2004–2007 at eight headwater catchments at the Kings River Experimental Watersheds in southern Sierra Nevada. Four catchments are snow-dominated, and four receive a mix of rain and snow. Results of diagnostic tools of mixing models indicate that Ca^{2+}, Mg^{2+}, K^+ and Cl^- behaved conservatively in the streamflow at all catchments, reflecting mixing of three endmembers. Using endmember mixing analysis, the endmembers were determined to be snowmelt runoff (including rain on snow), subsurface flow and fall storm runoff. In seven of the eight catchments, streamflow was dominated by subsurface flow, with an average relative contribution (% of streamflow discharge) greater than 60%. Snowmelt runoff contributed less than 40%, and fall storm runoff less than 7% on average. Streamflow peaked 2–4 weeks earlier at mixed rain–snow than snow-dominated catchments, but relative endmember contributions were not significantly different between the two groups of catchments. Both soil water in the unsaturated zone and regional groundwater were not significant contributors to streamflow. The contributions of snowmelt runoff and subsurface flow, when expressed as discharge, were linearly correlated with streamflow discharge (R^2 of 0.85–0.99). These results suggest that subsurface flow is generated from the soil–bedrock interface through preferential pathways and is not very sensitive to snow–rain proportions. Thus, a declining of the snow–rain ratio under a warming climate should not systematically affect the processes controlling the streamflow generation at these catchments.

Loboschefsky, E., A. Massoudieh, G.M. Benigno, T.R. Sommer, T. Ginn, K. Rose, and F. Loge (2010). Application of an individual based model of San Francisco Estuary striped bass to explore possible mechanisms associated with the observed disconnect between juvenile and adult population estimates. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

In the San Francisco Estuary (Estuary) abundances of striped bass (Morone saxatilis) have fluctuated greatly over time, with a sharp decline beginning around 2000. Coincident with similar declines in several other pelagic fish species, the continued decline of these species became know as the Pelagic Organism Decline (POD). One unique feature of the POD specific to striped bass is a disconnect between the “Age-0” Fall Midwater Trawl (FMWT)/ Summer Townet Survey (TNS) abundance indices and adult abundance measures. Specifically, as the FMWT/TNS indices declined in the mid- 1990’s, adult abundance indices remained relatively stable. Several mechanisms have been proposed as possible causes to this observed disconnect, including changes in adult striped bass sex ratios and changes in egg/larval mortality. Changes in adult sex ratios, specifically the loss of adult females, may have contributed to a decreased egg supply, subsequently leading to declines in the FMWT/TNS indices. At the same time, a compensatory decrease in mortality in the Age 1/Age 2 life-stages may have led to the stable adult abundances. Alternatively, an increase in egg/larval mortality rates may have led to the declining FMWT/TNS indices, and a compensatory decrease in mortality in the Age 1/Age 2 life-stages led to the stable adult abundances. In the study presented herein, we first apply an individual-based model (IBM) of San Francisco Estuary striped bass to evaluate the relative roles that changing adult sex ratios and egg/larval mortality have upon the “Age-0” and adult abundance measures. Next we apply the IBM to evaluate three possible mechanisms that may contribute to observed changes in adult sex ratios: (1) skipped years in spawning, (2) changes in female mortality rates, and (3) changes in sex ratios at hatch.

Loboschefsky, E., G.M. Benigno, T.R. Sommer, T. Ginn, A. Massoudieh, K. Rose, and F. Loge (2010). Bioenergetic modeling of striped bass in the San Francisco Estuary. IEP 2010 Annual Workshop and the 6th Biennial Bay–Delta Science Conference. Workshop presentation at the California State University, Sacramento and the Sacramento Convention Center, Sacramento, CA.

Striped bass (Morone saxatilis) are the top predator in the San Francisco Estuary (Estuary) and therefore have the potential to strongly structure communities of lower trophic levels. In this study, we (1) developed a method to estimate abundances of sub-adult (age 1 and age 2) striped bass, (2) applied a bioenergetics model of sub-adult and adult striped bass to quantify long-term consumption patterns from 1969 through 2004 in the Estuary, (3) evaluated how consumption varied by age and sex, and (4) identified factors impacting the resulting consumption estimates. On a ‘per capita’ basis, individual total and prey fish consumption increased after 1994 for age 2 cohorts, and individual prey fish consumption increased after 1990 for age 1 cohorts. Conversely, individual total and prey fish consumption by adult (age 3+) striped bass decreased over the period analyzed. This decline in individual consumption over the study period appeared to be related to a decline in size-at-age of adult cohorts. As expected, both population total and prey fish consumption by all cohorts (ages 1 though 6) of striped bass were highly correlated to population abundance estimates. Hence, the long-term trends in population consumption by each cohort closely followed their respective population abundance trends. Population total and prey fish consumption by sub-adult (age 1 and age 2) striped bass was found to be similar to the population consumption by adult striped bass, due largely to the population numbers of sub-adults. Unlike adult striped bass that are known to emigrate and forage in the ocean, the majority of sub-adult striped bass reside permanently within the Estuary, creating the possibility that consumption by the relatively abundant sub-adult population could have significant impacts upon estuarine prey species.

Logan, S. H. (1990). "Global warming and the Sacramento-San Joaquin Delta " California Agriculture 44(3): 16-18.
        The likelihood of global warming and its potential consequences are major concerns to global climate researchers, government officials, and members of the public. Conferences, workshops, and various publications have considered the effects of higher global temperatures on ocean levels, rainfall, and other climatic variables.

Logan, S. H. (1990). "SIMULATING COSTS OF FLOODING UNDER ALTERNATIVE POLICIES FOR THE SACRAMENTO SAN-JOAQUIN RIVER DELTA." Water Resources Research 26(5): 799-809.

Long, E. R. a. R. M. (1992). Evaluation of the extent and magnitude of biological effects associated with chemical contaminants in San Francisco Bay, California. Seattle, WA, National Ocean Service, Office of Ocean Resources Conservation and Assessment.
        The objective of the report was to assess the spatial extent and magnitude (severity) of measures of adverse biological effects associated with chemical contaminants in San Francisco Bay. Chemical contaminants potentially toxic to marine and estuarine organisms have been detected and quantified in the sediments and biota of San Francisco Bay. These chemicals have the potential to be harmful to valued marine resources of San Francisco Bay if they occur in sufficiently high concentrations and are bioavailable. The data from these different studies, collectively, provide substantial evidence that toxicant-related effects occur among at least some of the resident biota of the estuary. However, the available data preclude an identification of the spatial patterns in toxicant-associated effects with a high degree of spatial resolution. The data are from analyses of either highly mobile fish, transient water masses, or small numbers of samples. Substantially more data available from numerous sediment toxicity tests, if merged, could provide needed information on the spatial extent of toxicant-associated effects. The approach taken in the report was to assemble as much data as possible from different investigations to piece together an estimate of the extent and severity of effects.

Lopez, C. B., J. E. Cloern, et al. (2006). "Ecological values of shallow-water habitats: Implications for the restoration of disturbed ecosystems." Ecosystems 9(3): 422-440.
        A presumed value of shallow-habitat enhanced pelagic productivity derives from the principle that in nutrient-rich aquatic systems phytoplankton growth rate is controlled by light availability, which varies inversely with habitat depth. We measured a set of biological indicators across the gradient of habitat depth within the Sacramento-San Joaquin River Delta (California) to test the hypothesis that plankton biomass, production, and pelagic energy flow also vary systematically with habitat depth. Results showed that phytoplankton biomass and production were only weakly related to phytoplankton growth rates whereas other processes (transport, consumption) were important controls. Distribution of the invasive clam Corbicula fluminea was patchy, and heavily colonized habitats all supported low phytoplankton biomass and production and functioned as food sinks. Surplus primary production in shallow, uncolonized habitats provided potential subsidies to neighboring recipient habitats. Zooplankton in deeper habitats, where grazing exceeded phytoplankton

production, were likely supported by significant fluxes of phytoplankton biomass from connected donor habitats. Our results provide three important lessons for ecosystem science: (a) in the absence of process measurements, derived indices provide valuable information to improve our mechanistic understanding of ecosystem function and to benefit adaptive management strategies; (b) the benefits of some ecosystem functions are displaced by water movements, so the value of individual habitat types can only be revealed through a regional perspective that includes connectedness among habitats; and (c) invasive species can act as overriding controls of habitat function, adding to the uncertainty of management outcomes.

Losi, M. E., and W.T. Frankenberger (1997). "Bioremediation of selenium in soil and water." Soil Science 162(10): 692-702.
Selenium (Se) contamination of agricultural soils and drainage water in California's San Joaquin Valley has been identified as the cause of death and deformation in migratory waterfowl. Within the last decade, significant research has focused on developing ways of removing Se from impacted soils and waters. Microbially mediated reactions have been identified which may have applications in this regard. These include transformations of soluble, toxic Se oxyanions into less toxic volatile or precipitated forms. This review discusses Se as an environmental contaminant, with emphasis on biotransformations that largely control the behavior of Se in soil/water systems. The major focus is on recent advances related to the development of useful techniques for bioremediation of Se-contaminated soils and water.

Lougee, L. A., S. M. Bollens, et al. (2002). "The effects of haloclines on the vertical distribution and migration of zooplankton." Journal of Experimental Marine Biology and Ecology 278(2): 111-134.
While the influence of horizontal salinity gradients on the distribution and abundance of planktonic organisms in estuaries is relatively well known, the effects of vertical salinity gradients (haloclines) are less well understood. Because biological, chemical, and physical conditions can vary between different salinity strata, an understanding of the behavioral response of zooplankton to haloclines is crucial to understanding the population biology and ecology of these organisms. We studied four San Francisco Bay copepods, Acartia (Acartiura) spp., Acartia (Acanthacartia) spp., Oithona davisae, and Tortanus dextrilobatus, and one species of larval fish (Clupea pallasi), in an attempt to understand how and why zooplankton respond to haloclines. Controlled laboratory experiments involved placing several individuals of each species in two 2-m-high tanks, one containing a halocline (magnitude varied between 1.4 and 10.0 psu) and the other without a halocline, and recording the location of each organism once every hour for 2-4 days using an automated video microscopy system. Results indicated that most zooplankton changed their vertical distribution and/or migration in response to haloclines. For the smaller taxa (Acartiura spp., Acanthacartia spp., and O. davisae), this behavior took the form of accumulating in or below the halocline, while the effects on the larger species (C. pallasi and T. dextrilobatus) were more subtle. C. pallasi yolk sac and 3- to 6-day-old larvae seemed to pause or remain in the halocline during their diel migration, while 14- to 17-day-old larvae appeared to avoid the halocline by remaining in deeper, more saline water. There were very few statistically significant effects of haloclines on the vertical distribution of T. dextrilobatus. Subsequent mortality experiments with Acartiura spp., Acanthacartia spp. and T. dextrilobatus indicated that the behavioral changes seen in the halocline studies were not associated with any salinity-induced mortality per se, although more subtle affects of physiological stress could not be ruled out. These results point to a high degree of flexibility in vertical migration behavior within a given species as well as large variation between species. Such behavioral flexibility is likely to be very important in allowing planktonic organisms generally, and estuarine organisms in particular, to maintain or alter position relative to currents, food, and predators.

Louie, S. (2010). Lower American River and Lake Natoma methylmercury TMDL public participation. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The lower American River (LAR) from Folsom Dam to the Sacramento River is

impaired due to elevated levels of methylmercury in fish that pose risks to human and wildlife health. Available data suggest that 33% and 21% of fish in the LAR and Lake Natoma, respectively, exceed the USEPA criterion of 0.3 ppm methylmercury for the protection of human health. Fish tissue levels will likely need to be reduced by 15-80% to protect humans and wildlife that consume LAR fish. The mercury control program will likely need to focus on reducing sources of both methylmercury and inorganic mercury to achieve fish methylmercury concentrations that are protective of human and wildlife health. The Central Valley Water Board is developing a methylmercury TMDL (total maximum daily load) control program for the LAR to resolve the mercury impairment. Public participation is a vital component of developing the methylmercury control program. Public participation will enable stakeholders to become more informed about the impairment and about required elements of a TMDL control program. In addition, stakeholders can recommend options for numeric targets, allocations, implementation actions, etc., and identify potential environmental impacts. There will be a variety of opportunities for public participation during the development of the TMDL control program. This poster gives scoping-level information about the TMDL process and offers an interactive way for the public to provide verbal and written comments, ideas, and questions. Relevance to Bay-Delta Program Objectives: The goal of developing and implementing a TMDL control program for the lower American River is to improve water quality by restoring the beneficial use of safe fish consumption by humans and wildlife. A key objective is to develop management practices to minimize methylmercury and inorganic mercury while retaining ecosystem benefits.

Low, A., and M. Palmer-Zwahlen (2010). Comprehensive constant fractional marking program for Central Valley fall-run chinook salmon. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Over 32 million fall-run Chinook salmon are produced each year at five hatcheries in California’s Central Valley. This production contributes to major sport and commercial fisheries in ocean and inland areas. Until 2007, only experimental releases of fall-run Chinook were externally marked and coded-wire tagged on a consistent basis. In recent years, the Central Valley Project Improvement Act (CVPIA) program, the Bay-Delta Program, and other state and federally-mandated programs have provided significant funding for salmon habitat restoration programs, with the goal of increasing natural production in the Central Valley. Due to the current low rates of marking/tagging of hatchery fish, evaluation of these restoration programs, and harvest management programs, is limited by the inability to assess the relative contribution of hatchery and natural production of fall-run Chinook in the ocean harvest, inland harvest, in-river spawning escapements, and hatchery returns. In 2006, the CALFED Ecosystem Restoration Program funded the implementation of a Central Valley-wide Constant Fractional Marking/coded-wire tagging program for hatchery production releases of fall-run Chinook salmon. Based on statistical studies, the program targeted marking/tagging at a consistent 25% rate. Specific goals of the program include: 1. Evaluation of the the contribution rates of hatchery fish to Central Valley Chinook salmon populations, 2. Evaluation of the Central Valley propagation program’s genetic and ecological effects on natural Chinook populations, 3. Estimation of exploitation rates of hatchery and natural Central Valley Chinook salmon in ocean and inland fisheries, 4. Evaluation of the success of restoration actions designed to increase natural production of Central Valley Chinook salmon, 5. Evaluation of the recovery of listed stocks of Chinook salmon. Due to the short period of time and large numbers of fall-run Chinook that needed to be marked/tagged, traditional manual marking/tagging was not be feasible at the 25% rate. Four automated marking/tagging systems, AutoFish Systems, were purchased to mark/tag production releases. Marking/tagging was conducted each spring from 2007 through 2010 (Brood Year 2006 through 2009 fall-run Chinook) at Coleman National Fish Hatchery, Feather River Hatchery and Annex, Nimbus Hatchery, and Mokelumne River Hatchery. Approximately 32 million fall-run were processed each year through the automated trailers; approximately 8 million fish were marked/tagged. Preliminary analysis of coded-wire tag data from spawning returns in the fall of 2008 and 2009 indicate a highly variable proportion of hatchery-origin fish in the spawning escapement in Central Valley streams. Results also indicate a variable straying rate of hatchery fish to

out-of-basin areas. This program will provide the Bay-Delta Program with specific information needed to evaluate ecosystem restoration actions and goals related to improving conditions for Central Valley Chinook salmon. Specifically, the project will provide the basis for (i) evaluating and revising Central Valley salmon hatchery operations to result in population augmentation without detrimental effects on wild populations; (ii) being able to track restoration of all races of Chinook salmon; (iii) tracking whether targets for population restoration of Chinook salmon are being reached.

Lu, X. Q., I. Werner, et al. (2005). "Geochemistry and bioavailability of metals in sediments from northern San Francisco Bay." Environment International 31(4): 593-602.

In this study, metals (Be, Cr, Mn, Fe, Ni, Cu, Zn, Ag, Cd, Pb and Hg) in the fine-grained fraction (<63 mu m) from 12 sites at different locations in northern San Francisco Bay over a year period from March 2000 to March 2001 were analyzed after acid extraction. The results showed that metal concentrations in the sediments varied from site to site, whereas some of them were found elevated with respect to the sediment of Tomales Bay, CA, which has little contamination history, indicating an enrichment of the metals in the sediment samples analyzed. Sediment toxicity and bioaccumulation evaluation by a clam species, Macoma nasuta, exposed to the sediment samples collected from the six sampling sites was carried out. The results showed that the sediment samples tested significantly reduced clam survival. Toxicity of the sediments to the clam was, in part, related to elevated metal concentrations in the sediments. In order to examine geochemistry of the metals and to understand potential correlations between metal concentrations and geochemical matrix elements of the sediments, bioavailability and toxicity of the metals, detailed analysis of metal concentrations associated with total organic carbon and the Fe-oxy- hydroxides in the sediment samples was performed. The analysis showed that sediment geochemistry appeared to influence metal bioavailability and may have important impacts on the toxicity of these metals to the clam.

Lucas, L. V., S. Baek, J. Thompson, M.D. Dettinger, and M. Stacey (2010). The physical-biological functioning of an existing flooded island: Lessons from a numerical model. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

In the next 50 years, the Sacramento-San Joaquin Delta is likely to be characterized by many more flooded farm tracts than currently exist. The future flooding of Delta islands may be the result of unplanned flood- or earthquake-induced levee failure, or of proactive flooding for habitat restoration and the protection of water quality, property, and human life. Measurement and modeling of physical and biological functions within existing Delta flooded islands can help hone our expectations of future post-flood habitat function, and provide valuable design information to guide planned flooding efforts. A three-dimensional numerical model of hydrodynamics, water temperature, and phytoplankton dynamics was applied to Mildred Island, an existing Delta flooded island. Driven and validated with measurements from intensive field studies, this model performs well in capturing tidally and atmospherically driven dynamics of current velocity, stage, and water temperature. Phytoplankton biomass variability, which is regulated by three-dimensional hydrodynamics as well as by light-limited growth, zooplankton grazing, and clam grazing, is also characterized well by the model. We are using the model to test the sensitivity of this island habitat to changes in geometry, atmospheric forcing, water clarity, and grazing. The goals are to 1) better understand the combination of physical and biological forcings that make Mildred Island one of the most productive habitats in the largely unproductive Delta; 2) assess how this habitat might function in the future; 3) shape our expectations of the functioning of future flooded islands; and 4) provide insights regarding the effects of controllable habitat attributes to inform potential future planned flooding of subsided Delta farm lands.

Lucas, L. V. and J. E. Cloern (2002). "Effects of tidal shallowing and deepening on phytoplankton production dynamics: a modeling study." Estuaries 25(497-507).

Processes influencing estuarine phytoplankton growth occur over a range of time scales, but many conceptual and numerical models of estuarine phytoplankton production dynamics neglect mechanisms occurring on the shorter (e.g., intratidal) time scales. We used a numerical model to explore the influence of short time-scale variability in phytoplankton sources and sinks on long-term growth in an idealized water column that shallows and deepens with the semidiurnal tide. Model results show that tidal fluctuations in water surface elevation can determine whether long-term phytoplankton growth is positive or negative. Hourly scale interactions influencing weekly-scale to monthly scale phytoplankton dynamics include intensification of the depth-averaged benthic grazing effect by water column shallowing and enhancement of water column photosynthesis when solar noon coincides with low tide. Photosynthesis and benthic consumption may modulate over biweekly time scales due to spring-neap fluctuations in tidal range and the 15-d cycle of solar noon-low tide phasing. If tidal range is a large fraction of mean water depth, then tidal shallowing and deepening may significantly influence net phytoplankton growth. In such a case, models or estimates of long-term phytoplankton production dynamics that neglect water surface fluctuations may overestimate or underestimate net growth and could even predict the wrong sign associated with net growth rate.

Lucas, L. V., J. E. Cloern, et al. (1998). "Does the Sverdrup critical depth model explain bloom dynamics in estuaries?" Journal of Marine Research 56: 375-415.
In this paper we use numerical models of coupled biological-hydrodynamic processes to search for general principles of bloom regulation in estuarine waters. We address three questions: What are the dynamics of stratification in coastal systems as influenced by variable freshwater input and tidal stirring? How does phytoplankton growth respond to these dynamics? Can the classical Sverdrup Critical Depth Model (SCDM) be used to predict the timing of bloom events in shallow coastal domains such as estuaries? We present results of simulation experiments which assume that vertical transport and net phytoplankton growth rates are horizontally homogeneous. In the present approach the temporally and spatially varying turbulent diffusivities for various stratification scenarios are calculated using a hydrodynamic code that includes the Mellor-Yamada 2.5 turbulence closure model. These diffusivities are then used in a time- and depth-dependent advection-diffusion equation, incorporating sources and sinks, for the phytoplankton biomass. Our modeling results show that, whereas persistent stratification greatly increases the probability of a bloom, semidiurnal periodic stratification does not increase the likelihood of a phytoplankton bloom over that of a constantly unstratified water column.

Lucas, L. V., J. E. Cloern, et al. (2002). "Functional variability of habitats within the Sacramento-San Joaquin Delta: restoration implications." Ecological Applications 12: 1528-1547.
We have now entered an era of large-scale attempts to restore ecological functions and biological communities in impaired ecosystems. Our knowledge base of complex ecosystems and interrelated functions is limited, so the outcomes of specific restoration actions are highly uncertain. One approach for exploring that uncertainty and anticipating the range of possible restoration outcomes is comparative study of existing habitats similar to future habitats slated for construction. Here we compare two examples of one habitat type targeted for restoration in the Sacramento-San Joaquin River Delta. We compare one critical ecological function provided by these shallow tidal habitats-production and distribution of phytoplankton biomass as the food supply to pelagic consumers. We measured spatial and short-term temporal variability of phytoplankton biomass and growth rate and quantified the hydrodynamic and biological processes governing that variability. Results show that the production and distribution of phytoplankton biomass can be highly variable within and between nearby habitats of the same type, due to variations in phytoplankton sources, sinks, and transport. Therefore, superficially similar, geographically proximate habitats can function very differently, and that functional variability introduces large uncertainties into the restoration process. Comparative study of existing habitats is one way ecosystem science can elucidate and potentially minimize restoration uncertainties, by identifying processes shaping habitat functionality, including those that can be controlled in the restoration design.

Lucas, L. V., J. R. Koseff, et al. (1999). "Processes governing phytoplankton blooms

in estuaries. I: The local production-loss balance." Marine Ecology Progress Series 187: 1-15.
The formation and spatial distribution of phytoplankton blooms in estuaries are controlled by (1) local mechanisms, which determine the production-loss balance for a water column at a particular spatial location (i.e. control if a bloom is possible), and (2) transport-related mechanisms, which govern biomass distribution (i.e. control if and where a bloom actually occurs). In this study, the first of a 2-paper series, we use a depth-averaged numerical model as a theoretical tool to describe how interacting local conditions (water column height, light availability, benthic grazing) influence the local balance between phytoplankton sources and sinks. We also explore trends in the spatial variability of the production-loss balance across the topographic gradients between deep channels and lateral shoals which are characteristic of shallow estuaries. For example, under conditions of high turbidity and slow benthic grazing the highest rates of phytoplankton population growth are found in the shallowest regions. On the other hand, with low turbidity and rapid benthic grazing the highest growth rates occur in the deeper areas. We also explore the effects of semidiurnal tidal variation in water column height, as well as spring-neap variability. Local population growth in the shallowest regions is very sensitive to tidal-scale shallowing and deepening of the water column, especially in the presence of benthic grazing. A spring-neap signal in population growth rate is also prominent in the shallow areas. Population growth in deeper regions is less sensitive to temporal variations in tidal elevation. These results show that both shallow and deep regions of estuaries can act as sources or sinks for phytoplankton biomass, depending on the local conditions of mean water column height, tidal amplitude, light-limited growth rate, and consumption by grazers.

Lucas, L. V., J. R. Koseff, et al. (1999). "Processes governing phytoplankton blooms in estuaries. II: The role of horizontal transport." Marine Ecology Progress Series 187: 17-30.
The development and distribution of phytoplankton blooms in estuaries are functions of both local conditions (i.e. the production-loss balance for a water column at a particular spatial location) and large-scale horizontal transport. In this study, the second of a 2-paper series, we use a depth-averaged hydrodynamic-biological model to identify transport-related mechanisms impacting phytoplankton biomass accumulation and distribution on a system level. We chose South San Francisco Bay as a model domain, since its combination of a deep channel surrounded by broad shoals is typical of drowned-river estuaries. Five general mechanisms involving interaction of horizontal transport with variability in local conditions are discussed. Residual (on the order of days to weeks) transport mechanisms affecting bloom development and location include residence time/export, import, and the role of deep channel regions as conduits for mass transport. Interactions occurring on tidal time scales, i.e. on the order of hours) include the phasing of lateral oscillatory tidal flow relative to temporal changes in local net phytoplankton growth rates, as well as lateral sloshing of shoal-derived biomass into deep channel regions during ebb and back into shallow regions during flood tide. Based on these results, we conclude that: (1) while local conditions control whether a bloom is possible, the combination of transport and spatial-temporal variability in local conditions determines if and where a bloom will actually occur; (2) tidal-time-scale physical-biological interactions provide important mechanisms for bloom development and evolution. As a result of both subtidal and tidal-time-scale transport processes, peak biomass may not be observed where local conditions are most favorable to phytoplankton production, and inherently unproductive areas may be regions of high biomass accumulation.

Lucas, L. V., D. M. Sereno, et al. (2006). "Intradaily variability of water quality in a shallow tidal lagoon: Mechanisms and implications." Estuaries and Coasts 29(5): 711-730.
Although surface water quality and its underlying processes vary over time scales ranging from seconds to decades, they have historically been studied at the lower (weekly to interannual) frequencies. The aim of this study was to investigate intradaily variability of three water quality parameters in a small freshwater tidal lagoon (Mildred Island, California). High frequency time series of specific conductivity, water temperature, and chlorophyll a at two locations within the

habitat were analyzed in conjunction with supporting hydrodynamic, meteorological, biological, and spatial mapping data. All three constituents exhibited large amplitude intradaily (e.g., semidiurnal tidal and diurnal) oscillations, and periodicity varied across constituents, space, and time. Like other tidal embayments, this habitat is influenced by several processes with distinct periodicities including physical controls, such as tides, solar radiation, and wind, and biological controls, such as photosynthesis, growth, and grazing. A scaling approach was developed to estimate individual process contributions to the observed variability. Scaling results were generally consistent with observations and together with detailed examination of time series and time derivatives, revealed specific mechanisms underlying the observed periodicities, including interactions between the tidal variability, heating, wind, and biology. The implications for monitoring were illustrated through subsampling of the data set. This exercise demonstrated how quantities needed by scientists and managers (e.g., mean or extreme concentrations) may be misrepresented by low frequency data and how short-duration high frequency measurements can aid in the design and interpretation of temporally coarser sampling programs. The dispersive export of chlorophyll a from the habitat exhibited a fortnightly variability corresponding to the modulation of semidiurnal tidal currents with the diurnal cycle of phytoplankton variability, demonstrating how high frequency interactions can govern long-term trends. Process identification, as through the scaling analysis here, can help us anticipate changes in system behavior and adapt our own interactions with the system.

Lucas, L. V. and A. R. Stewart (2005). Final Report: Transport, transformation and defects of selenium and carbon in the delta of the Sacramento-San Joaquin rivers: Implications for ecosystem restoration. CALFED Ecosystem Restoration Program Agreement No. 4600001955, Project No. ERP-01-C07.

Lucas, L. V., J. K. Thompson, et al. (2009). "Why are diverse relationships observed between phytoplankton biomass and transport time?" Limnology and Oceanography 54: 381-390.
Transport time scales such as flushing time and residence time are often used to explain variability in phytoplankton biomass. In many cases, empirical data are consistent with a positive phytoplankton-transport time relationship (i.e., phytoplankton biomass increases as transport time increases). However, negative relationships, varying relationships, or no significant relationship may also be observed. We present a simple conceptual model, in both mathematical and graphical form, to help explain why phytoplankton may have a range of relationships with transport time, and we apply it to several real systems. The phytoplankton growth-loss balance determines whether phytoplankton biomass increases with, decreases with, or is insensitive to transport time. If algal growth is faster than loss (e. g., grazing, sedimentation), then phytoplankton biomass increases with increasing transport time. If loss is faster than growth, phytoplankton biomass decreases with increasing transport time. If growth and loss are approximately balanced, then phytoplankton biomass is relatively insensitive to transport time. In analyses of several systems, portions of an individual system, or time periods, apparent insensitivity of phytoplankton biomass to changes in transport time could arise due to the superposition of cases with different phytoplankton-transport time relationships. Thus, in order to understand or predict responses of phytoplankton biomass to changes in transport time, the relative rates of algal growth and loss must be known.

Luengen, A., N. Fisher, and B.A. Bergamaschi (2010). Factors affecting the bioavailability of methylmercury to phytoplankton and amphipods. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
These results are the synthesis of series of experiments that used radioisotopes to follow the uptake of methylmercury (Me203Hg) by phytoplankton and its subsequent trophic transfer to amphipods. In experiments looking at the factors that affected Me203Hg bioavailability to phytoplankton (Cyclotella meneghiniana), we found that dissolved organic matter (DOM) was the main factor that affected algal accumulation Me203Hg. Volume concentration factors (VCFs), or the concentration of MeHg in cells divided by the amount of MeHg in an equivalent amount of water, are

highest (300,000 or more) when concentrations of organic matter were low. VCFs were also affected by Cl- concentrations. Under low DOM concentrations, algal cells grown in high (28,000 μM) Cl- concentrations had VCFs > 300,000 whereas cells grown in low (230 μM) Cl- concentrations had VCFs around 200,000. A similar pattern was observed when both Cl- treatments had high concentrations of organic matter from Mandeville Tip in the Delta. Low concentrations of Cl- combined with high organic matter resulted in VCFs around 100,000 or less. When Me203Hg labeled phytoplankton were fed to amphipods (Hyalella azteca), the initial concentration in the phytoplankton determined the amount that was passed onto the grazers. This result means that DOM is an important parameter for predicting MeHg accumulation in the food web. However, DOM does not affect the loss of Me203Hg from amphipods; assimilation efficiencies of ingested MeHg in the amphipods were around 65-70% for both the low and high DOM treatments. These results are an first important step in understanding the factors that govern the bioavailability and subsequent trophic transfer of MeHg in food webs.

Luengen, A. C., C. S. Friedman, et al. (2000). "Immune responses of two species of mussels (Mytilus californianus and Mytilus galloprovincialis/trossulus hybrid) to pollutants in San Francisco Bay, CA." Journal of Shellfish Research 19(1).

Since mussels (Mytilus californianus) are routinely deployed in San Francisco Bay, California to monitor concentrations of contaminants in their tissues, this study was initiated to determine whether the elevated concentrations of some of those contaminants correlated with measures of variations in their immune response. Preliminary data from the latter measurements indicate that mussels from relatively contaminated sites exhibit elevated immune responses when compared with mussels from relatively pristine sites. This includes the following immune parameters: (1) number of hemocytes, (2) percentage of cells that phagocytosed particles, and (3) a phagocytic index, which describes how many particles were engulfed by phagocytic cells. Additionally, M. californianus, which does not live naturally in the Bay, appeared to show elevated immune responses when compared to M. galloprovincialis/trossulus hybrids that are endemic to the Bay. This disparity also indicates that M. californianus, which has been the species historically deployed as a biomonitor in the Bay, may not be the most appropriate species. Finally, this preliminary research has lead to the development of a new technique to evaluate phagocytosis in the mussel cell's hemolymph because the cells were too sensitive to the centrifugation step and the washing steps used in established methods.

Luengen, A. C., C. S. Friedman, et al. (2004). "Evaluation of mussel immune responses as indicators of contamination in San Francisco Bay." Marine Environmental Research 57(3): 197-212.

Several immune parameters were evaluated in two species of mussels (Mytilus californianus and M. galloprovincialis/M. trossulus) as bioindicators of contaminant effects. The mussels were deployed in San Francisco Bay Estuary and a control site at Bodega Marine Laboratory. Assays for phagocytosis and phagocytic index (average number of particles engulfed per hemocyte) were conducted with hemocytes in their own hemolymph-the Serum method. The responses were compared with contaminant concentrations in those mussels. For both species, the contaminated South Bay Dumbarton Bridge and Redwood Creek sites had elevated phagocytosis relative to the Bodega control site, indicating contaminant stress. The results also showed that M. californianus had higher percentages of phagocytosis (74%) and a higher phagocytic index (4.6 particles per cell) than those of M. galloprovincialis/M. trossulus (60% phagocytosis and 3.5 particles per cell). As there is a difference in immune response to contaminants, it is suggested that future San Francisco Estuary monitoring should be conducted with endemic M. galloprovincialis/M. trossulus rather than with the currently utilized M. californianus, which is not found in the estuary.

Luengen, A. C., P. T. Raimondi, et al. (2007). "Contrasting biogeochemistry of six trace metals during the rise and decay of a spring phytoplankton bloom in San Francisco Bay." Limnology and Oceanography 52(3): 1112-1130.

The spring 2003 phytoplankton bloom in South San Francisco Bay (South Bay) affected the cycling of Mn, Co, Zn, Ni, and Pb, but not Cu. We followed this diatom bloom for 2 months, capturing a peak in chlorophyll a (Chl a) of >150 mu g L super(-1) and then an increase in dissolved organic carbon of >400 mu mol L super(-1) as phytoplankton decomposed. To determine how the stages of the bloom affected metal concentrations, we used principal component analysis to reduce our 15 water chemistry variables into a bloom factor, a sorbent factor, and a decay factor. Increasing values of the bloom factor, which was a composite of dissolved oxygen, Chl a, and other variables, significantly accounted for reductions in dissolved Mn, Ni, and Pb. We attributed those declines to microbial oxidation, phytoplankton uptake, and sorption onto phytoplankton, respectively. In contrast, dissolved Cu concentrations were not explained by either the bloom or decay factors, consistent with previous studies showing its strong organic complexation and limited bioavailability in South Bay. The decay factor significantly accounted for increases in dissolved Mn, Co, Zn, and Pb. Decomposing bloom material presumably caused suboxic conditions in surface sediments, resulting in release of metals to overlying waters during reductive dissolution of Mn and Fe (hydr)oxides. These alterations in metal cycling during a nutrient-enriched bloom were evidence of eutrophication. Annually, phytoplankton productivity has the potential to affect metal retention in the estuary; in 2003, 75% of Ni discharged into lower South Bay by wastewater treatment plants was cycled through phytoplankton.

Lund, J., E. Hanak, et al. (2007). Envisioning futures for the Sacramento-San Joaquin Delta. San Francisco, Public Policy Institute of California.

Lund, J. R., and W. Fleenor (2010). Environmental flows for native fishes. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Recent state legislation has required the development of flow prescriptions for supporting habitat conditions for desirable fishes in the Delta. In the larger professional literature, much is written on environmental flows for rivers and other water bodies, with little consensus on method (Richter et al. 1997; King and Louw 1998; others). This stems, in part, from the complexity involved (Moyle et al. 2010). Estimating human demands for water, both in quantity and quality, is fairly straightforward with well-established methods. Estimating flows for improving habitat conditions, particularly to support fishes with different and often conflicting life history strategies, is much more complex and is hampered by numerous uncertainties. For the Delta, these difficulties are compounded by major geological, biological, and engineering changes and transitions, particularly the return of subsided diked lands to aquatic habitat (subtidal, intertidal and floodplains), changes in water management within and upstream of the Delta, invasive species, and water contamination from upstream and in-Delta uses. These massive ongoing and potential changes cast doubt on the long-term value of empirical relationships often used to establish required Delta flows. As pointed out elsewhere (Lund et al. 2008), we are unlikely to ever resolve all these uncertainties and issues in the Delta before proactive actions are required – since courts are already requiring action. Initial flow prescriptions with a habitat and biological basis need to be developed to move the planning and policy process forward, even knowing that these prescriptions are based on incomplete data and understanding, and will undoubtedly be modified in the future. As support to the State Water Resources Control Board, we present a method for estimating fresh water flows needed to sustain viable populations of native fishes in the Delta. Three separate approaches to this problem are explored and illustrative quantities of water are estimated. While it is hoped these estimated flows might have some value in furthering discussions in light of the justifications and references provided, the greater value, for the time being, lies in the approach developed and applied here. This approach is developed largely to facilitate more transparent and scientific discussion of desirable freshwater flows and to suggest potential methods for their estimation.

Luoma, S. N., D.J. Cain, K. Ho, and A. Hutchinson (1983). "Variable tolerance to copper in two species from San Francisco Bay." Marine environmental research 10(4): 209-222.

In static toxicity experiments, tolerance to soluble Cu of the bivalve, Macoma balthica , and the copepod, Acartia clausi , varied substantially among populations sampled within San Francisco Bay. Intraspecific tolerance differed ten-fold or more for both species over relatively small distances, suggesting geographical isolation of populations is not a prerequisite for the development of intraspecific differences in tolerance by aquatic organisms.

Luoma, S. N., D. Cain, and C. Johansson (1985). "Temporal fluctuations of silver, copper, and zinc in the bivalve Macoma balthica at five stations in South San Francisco Bay." Hydrobiologia 129: 109-120.
Concentrations of Cu, Ag and Zn were measured in the soft tissues of the estuarine bivalve Macoma balthica in South San Francisco Bay at near-monthly intervals for periods of two to three years at four stations, and eight years at a metal-enriched station. The amplitude and frequency of fluctuations differed among stations and among metals. Fluctuations were greatest at stations with the greatest metal enrichment and with the least dilution and flushing of wastes. A consistent seasonal pattern of fluctuation in Cu and Ag concentrations was evident in M. balthica at the metal-enriched station. These seasonal changes in tissue metal concentrations appeared to be affected by metal inputs, hydrologic processes that may affect both metal concentrations and bioavailability, and seasonal changes in the weight of the bivalve. The contributions of each of these interacting factors could not be determined quantitatively. At the metal-enriched station significant variation in the amplitude of seasonal fluctuations was also evident from year to year. Interpretation of metal concentrations in bivalves from estuaries will require careful consideration of the processes which affect metal dynamics in these complex environments.

Luoma, S. N., and D.J.H. Phillips (1988). "Distribution, variability, and impacts of trace elements in San Francisco Bay." Marine Pollution Bulletin 19(9): 413-425.
Studies conducted to date in San Francisco Bay suggest that the trace elements of greatest concern are Ag, Cu, Se, Cd, and perhaps Hg. The distributions of these elements in the Bay are complex, as are temporal trends. Neither spatial nor temporal variability are fully documented. However, certain locations are considerably metal-enriched, coincident with locations of anthropogenic element input. Some evidence suggests that trace elements may exert detrimental impacts on benthic species in contaminated localities. Broad scale impacts will be difficult to determine without a fundamental understanding of ecological processes and a systematic description of the frequency of patches of metal disturbance in the Bay.

Luoma, S. N., R. Dagovitz, and E. Axtmann (1990). "Temporally intensive study of trace metals in sediments and bivalves from a large river-estuarine system: Suisun Bay/Delta in San Francisco Bay." The Science of the Total Environment 97(98): 685-712.
Distributions in time and space of Ag, Cd, Cr, Cu, Pb and Zn were determined in fine-grained sediments and in the filter-feeding bivalve Corbicula sp. of Suisun Bay/delta at the mouth of the Sacramento and San Joaquin Rivers in North San Francisco Bay. Samples were collected from seven stations at near-monthly intervals for 3 years. Aggregated data showed little chronic contamination with Ag, Zn and Pb in the river and estuary. Substantial chronic contamination with Cd, Cu and Cr in Suisun Bay/delta occurred, especially in Corbicula, compared with the lower San Joaquin River. Salinity appeared to have secondary effects, if any, on metal concentrations in sediments and metal bioavailability to bivalves. Space/time distributions of Cr were controlled by releases from a local industry. Analyses of time series suggested substantial inputs of Cu might originate from the Sacramento River during high inflows to the Bay, and Cd contamination had both riverine and local sources. Concentrations of metals in sediments correlated with concentrations in Corbicula only in annually or 3-year aggregated data. Condition index for Corbicula was reduced where metal contamination was most severe. The biological availability of Cu and Cd to benthos was greater in Suisun Bay than in many other estuaries. Thus small inputs into this system could have greater impacts than might occur elsewhere; and organisms were generally more sensitive indicators of enrichment than sediments in this system.

Luoma, S. N., A. van Geen, B.G. Lee, and J.E. Cloern (1998). "Metal uptake by phytoplankton during a bloom in South San Francisco Bay: Implications for metal cycling in estuaries." Limnology and Oceanography 43(5): 1007-1016.

The 1994 spring phytoplankton bloom in South San Francisco Bay caused substantial reductions in concentrations of dissolved Cd, Ni, and Zn, but not Cu. We estimate that the equivalent of 60% of the total annual input of Cd, Ni, and Zn from local waste-water treatment plants is cycled through the phytoplankton in South Bay. The results suggest that processes that affect phytoplankton bloom frequency or intensity in estuaries (e.g. nutrient enrichment) may also affect metal trapping. The bloom was characterized by hydrographic surveys conducted at weekly intervals for 9 weeks. Metal samples were collected from the water column on three occasions, timed to bracket the period when the bloom was predicted. Factors that might confound observations of biological influences, such as freshwater inputs, were relatively constant during the study. Before the bloom, concentrations of dissolved Cd were 0.81 ± 0.02 nmol kg-1, Zn concentrations were 19.8 ± 1.5 nmol kg-1, Ni were 42 ± 1.4 nmol kg-1, and Cu were 37 ± 1.4 nmol kg-1. These values are elevated relative to riverine and coastal end-members, reflecting inputs from wastewater and(or) sediments. At the height of the bloom, dissolved Zn, Cd, and Ni were reduced to 19, 50, and 75% of their prebloom concentrations, respectively: Dissolved Cu concentrations increased 20%. The mass of Cd taken up by phytoplankton was similar to the mass of Cd removed from solution if particle settling was considered, and Cd concentrations estimated in phytoplankton were higher than concentrations in suspended particulate material (SPM). Particulate concentrations of Zn and Ni during the bloom appeared to be dominated by the influence of changes in resuspension of Zn-and Ni-rich sediments.

Luoma, S. N., and L. Muscatine (2010). San Francisco Estuary and Watershed Science. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Now in its seventh year of publication, San Francisco Estuary and Watershed Science has continued to provide local researchers and policymakers with critical information about this complex, highly managed and ecologically important region. SFEWS fosters the communication of collaborative, peer-reviewed research by presenting original findings, reviews, techniques, and comments to broaden the current state of knowledge about the ecology of the San Francisco Bay-Delta region. Through publication in the journal researchers readily share their observations and conclusions with policymakers who are using their information for management applications. San Francisco Estuary and Watershed Science is an open access scholarly journal established to provide the opportunity for on-line publication of peer-reviewed papers dealing with all aspects of the San Francisco Bay-Delta estuary, its watershed, and adjacent coastal ocean.

Luoma, S. N., K. Ho, et al. (1981). "Copper tolerance among several populations of Acartia species in San Francisco Bay." Estuaries 4(3).
Tolerance to Cu differed among Acartia clausi from three locations in San Francisco Bay. Results of toxicity tests also differed between fall and winter at two of the locations, although consistent results within season and geographic area were found. Seasonal differences in tolerance followed seasonal changes in the bioavailability of Cu in the Bay, but differences between locations did not follow gradients in Cu stress established in other studies. In general, A. clausi from colder waters (9-11 degree C) were more tolerant to Cu than A. clausi from warmer waters (13-15 degree C), although all tests were conducted at 12 degree C. Differences in tolerance among populations of A. clausi were greater than differences between A. clausi and A. californiensis . In general, it appeared that localized gradients in stress may result in the development of genetically or physiologically distinct exotypes of A. clausi over short periods of time (months) or small distances within a single estuary.

Luoma, S. N. a. D. J. C. (1979). Fluctuations of copper, zinc, and silver in tellenid clams as related to freshwater discharge - south San Francisco Bay. San Francisco Bay: the Urbanized Estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 231-246.

Luster, R., and L. Winter (2010).
Integrated water operations and ecosystem decision support modeling: The Sacramento River-Delta Ecological Flows Tool. IEP 2010 Annual Workshop. Poster paper presented

at the California State University, Sacramento, Sacramento, CA.

Lynn, E. (2010). Managing an uncertain future: Climate change at the California Department of Water Resources. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Warmer temperatures, different patterns of precipitation and runoff, and rising sea levels increasingly affect the ability to manage water supplies and other natural resources. Adapting California's water management systems presents one of the most significant challenges for the 21st century. The Department of Water Resources has achieved a leadership role in both mitigation and adaptation strategies, as well as outreach. This poster will highlight major achievements, and feature key programs and initiatives that may serve as a template for other agencies. Strategies, approaches, and achievements include: GHG Emissions inventory, Hydroelectric energy efficiency programs, Integrated Regional Water Management grant program that now incorporates climate change into guidelines & proposal solicitation, Integration of Climate Change and Flood Management into California Water Plan Update 2009, Outreach exhibit and documentary on impacts of climate change to the State, "Save Our Water" conservation campaign, Central Valley Flood Protection Plan process, that will explicitly consider climate change impacts to flood management, Groundwater monitoring and water use efficiency legislation, Delta legislation and bond, Decision-Making and data improvement to help narrow uncertainty, Convening of National Research Council panel to evaluate sea level rise issues, Public Interest Energy Research Program Vulnerability Study, Paleohydrology studies of the San Joaquin, Sacramento, Klamath Rivers, 2009 Climate Action Team Report, DWR Sustainability Policy on goals and directions toward "greening", CEQA guidance document compliance support for department-wide use, Climate Action Plan to address climate change across all DWR programs and projects, Relevance: Incorporating variable climatic conditions into water management is directly relevant to the CALFED objective of sustainability.

Maak, E., W. McAnally, P. Craig, and C. Wallen (2010). Sediment modeling for the Delta Islands and Levees Feasibility Study. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The Sacramento - San Joaquin River Delta consists of a 700-mile network of controlled channels, 1,100 miles of levees, and 70-plus islands, most of which are well below sea level. The current system is a patchwork of projects implemented over the last 150 years primarily for land reclamation, flood control, navigation, and water delivery. Delta water supports $400 billon of the state economy, supplies two-thirds of the households, and provides habitat for many species. The Delta as a vital economic and ecologic resource for the residents of California and the nation is at risk. Continued development, changes in conveyance, subsidence, invasive species, seismic risk and weather/climate risks are likely going to challenge the system even further. While many models have been used in the system the 3-dimensional Environmental Fluid Dynamics Code (EFDC) has been chosen for this work. The 3-D hydrodynamic EFDC model will provide the necessary detailed predictions of water level and velocity for flooding analyses and all constituent transport processes from salinity to sediment to dissolved oxygen for existing conditions and predicted future scenarios, including plan alternatives. The numerical model has been designed to represent the major hydrodynamic processes, transport pathways and fate of nutrients, sediments, carbon and contaminants in surface waters and is capable of capturing subtle circulation patterns such as residual flows and density currents that are essential to representative transport of dissolved constituents and suspended materials. The purpose of the work described is to support the Delta Islands and Levees Feasibility Study (DILFS) and CALFED, specifically through the modeling of sediment transport, deposition and erosion. It is generally understood that sediment in the Delta can be beneficial, as when it nourishes wetlands and provides habitat for aquatic species that prefer turbid water or a specific substrate. It can have adverse effects when it produces a hostile habitat for aquatic species or clogs channels and outlet works that cause significant expense in the dredging of navigation channels, ports, and terminals. The EFDC suite of models will be used to support the development of water resource management plans for the Sacramento-San Joaquin Delta and provide managers with

quantitative evaluations and comparisons of the relative effectiveness of alternative plans to achieve the objectives in relation to known Delta issues related to water supply, water quality, flooding, navigation, recreation, sedimentation, ecosystem health, economics, and aesthetics.

Mac Nally, R., J. R. Thomson, et al. (2010). "Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR)." Ecological Applications 20(5): 1417-1430.

Four species of pelagic fish of particular management concern in the upper San Francisco Estuary, California, USA, have declined precipitously since ca. 2002: delta smelt (Hypomesus transpacificus), longfin smelt (Spirinchus thaleichthys), striped bass (Morone saxatilis), and threadfin shad (Dorosoma petenense). The estuary has been monitored since the late 1960s with extensive collection of data on the fishes, their pelagic prey, phytoplankton biomass, invasive species, and physical factors. We used multivariate autoregressive (MAR) modeling to discern the main factors responsible for the declines. An expert-elicited model was built to describe the system. Fifty-four relationships were built into the model, only one of which was of uncertain direction a priori. Twenty-eight of the proposed relationships were strongly supported by or consistent with the data, while 26 were close to zero (not supported by the data but not contrary to expectations). The position of the 2 per thousand isohaline (a measure of the physical response of the estuary to freshwater flow) and increased water clarity over the period of analyses were two factors affecting multiple declining taxa (including fishes and the fishes' main zooplankton prey): Our results were relatively robust with respect to the form of stock-recruitment model used and to inclusion of subsidiary covariates but may be enhanced by using detailed state-space models that describe more fully the life-history dynamics of the declining species.

MacCready, P. (2004). "Toward a Unified Theory of Tidally-Averaged Estuarine Salinity Structure." Estuaries 27(4): 561-570.

Equations are developed for the tidally-averaged, width-averaged estuarine salinity and circulation in a rectangular estuary. Width and depth may vary along the length of the channel, as may coefficients of vertical turbulent mixing and along channel diffusion. The system is reduced to a single first- order, nonlinear, ordinary differential equation governing the section-averaged salinity. A technique for specifying the ocean boundary condition is given, and solutions are found by numerical integration. Under different assumptions for the diffusion it is possible to reproduce the few existing analytical solutions, in particular the Hansen and Rattray (1965) Central Regime solution, and Chatwin's (1976) solution.The mathematical framework allows easy comparison of the results of different channel geometries and mixing coefficients. Of particular interest is the along-channel distribution of the diffusive fraction of up-estuary salt flux. It is shown that the Hansen and Rattray solution is always diffusion-dominated near the mouth. A theory is presented for estimating the diffusion coefficient within a tidal excursion of the mouth. It is shown that the resulting rapid along-channel increase of diffusion may explain some observed patterns of salinity structure: a decrease in both stratification and along-channel salinity gradient near the mouth. The theory is applied to the Delaware Estuary and Northern San Francisco Bay, and shows reasonable agreement with observed sensitivities of salt intrusion distance to river flow.

MacFarlane, R. B., and P.E. Benville Jr. (1986). "Primary and secondary stress responses of striped bass (Morone saxatilis) exposed to benzene." Marine Biology (Berlin) 92(2): 245-254.

Striped bass (Morone saxatilis) were collected from the San Francisco Bay-Delta estuary in 1982, from areas distant from pollution sources. After acclimatization, plasma cortisol concentration (primary response) and blood biochemicals indicative of energy mobilization (secondary responses) were followed in individuals exposed to sublethal levels of benzene for up to 21 d. Despite the persistence of benzene in blood and liver tissues for the exposure duration, stress responses were moderate and returned to control values within the initial 7 d. Blood and liver rapidly accumulated benzene to approximately 20 times the exposure concentrations (0.1 and 1.0 ppm). Concentrations of cortisol and secondary response variables were not proportional to benzene exposure or to accumulation levels,

however. Plasma cortisol concentrations increased two- to three-fold at 8 h and returned to control levels prior to 48 h exposure. Glucose, lactate, H+, protein and triglyceride concentrations were elevated during the initial 4 h to 7 d, with protein and triglyceride returning to normal levels prior to the other secondary response variables. From the perspective of the general adaptation syndrome (GAS), benzene activated the hypothalamo-pituitary-interrenal axis, resulting in clinical stress responses characteristics of an alarm reaction. The time-courses and amplitudes of primary and secondary responses to benzene suggest the sensory perception of a noxious agent eliciting mild, acute stress followed by adaptation.

MacFarlane, R. B., H.R. Harvey, M.J. Bowers, and J.S. Patton (1990). "Serum lipoproteins in striped bass (Morone saxatilis) - effects of starvation." Canadian Journal of Fisheries and Aquatic Sciences 47(4): 739-745.

Withholding food for 4 wk resulted in more extensive alterations within serum lipoprotein classes in striped bass (Morone saxatilis) than were evident in serum total lipids where only a decrease in triglycerides was significant. The apoproteins of each lipoprotein class changed little qualitatively due to starvation. Our results reflect the importance of maintaining high levels of lipoproteins as a transport system for lipids from storage depots to depleted tissues permitting survival during prolonged periods of starvation that are often encountered by fish during colder months and during spawning migrations. Furthermore, during starvation HDL appears to assume increased significance as a vehicle for the transport of structural lipids to maintain tissue integrity.

MacFarlane, R. B., and E.C. Norton. (2002). "Physiological ecology of juvenile chinook salmon (Oncorhynchus tshawytscha) at the southern end of their distribution, the San Francisco Estuary and Gulf of the Farallones, California." Fisheries Bulletin 100(2): 244-257.

Juvenile chinook salmon, Oncorhynchus tshawytscha, from natal streams in California's Central Valley demonstrated little estuarine dependency but grew rapidly once in coastal waters. We collected juvenile chinook salmon at locations spanning the San Francisco Estuary from the western side of the freshwater delta - at the confluence of the Sacramento and San Joaquin Rivers - to the estuary exit at the Golden Gate and in the coastal waters of the Gulf of the Farallones. Juveniles spent about 40 d migrating through the estuary at an estimated rate of 1.6 km/d or faster during their migration season (May and June 1997) toward the ocean. Mean growth in length (0.18 mm/d) and weight (0.02 g/d) was insignificant in young chinook salmon while in the estuary, but estimated daily growth of 0.6 mm/d and 0.5 g/d in the ocean was rapid (P less than or equal to 0.001). Condition (K factor) declined in the estuary, but improved markedly in ocean fish. Total body protein, total lipid, triacylglycerols (TAG), polar lipids, cholesterol, and nonesterified fatty acids concentrations did not change in juveniles in the estuary, but total lipid and TAG were depleted in ocean juveniles. As young chinook migrated from freshwater to the ocean, their prey changed progressively in importance from invertebrates to fish larvae. Once in coastal waters, juvenile salmon appear to employ a strategy of rapid growth at the expense of energy reserves to increase survival potential. In 1997, environmental conditions did not impede development: freshwater discharge was above average and water temperatures were only slightly elevated, within the species' tolerance. Data suggest that chinook salmon from California's Central Valley have evolved a strong ecological propensity for a ocean-type life history. But unlike populations in the Pacific Northwest, they show little estuarine dependency and proceed to the ocean to benefit from the upwelling-driven, biologically productive coastal waters.

Macleod, M., T. E. McKone, et al. (2005). "Mass balance for mercury in the San Francisco Bay Area." Environmental Science and Technology 39(17): 6721-6729.

We have developed and illustrated a general regional multi-species model that describes the fate and transport of mercury in three forms, elemental, divalent, and methylated, in a generic regional environment including air, soil, vegetation, water, and sediment. The objectives of the model are to describe the fate of the three forms of mercury in the environment and to determine the dominant physical sinks that remove mercury from the system. Chemical transformations between the three groups of mercury species are modeled by assuming constant ratios of

species concentrations in individual environmental media. We illustrate and evaluate the model with an application to describe the fate and transport of mercury in the San Francisco Bay Area of California. The model successfully rationalizes the identified sources with observed concentrations of total mercury and methyl mercury in the San Francisco Bay Estuary. The mass balance provided by the model indicates that continental and global background sources control mercury concentrations in the atmosphere but that loadings to water in the San Francisco Bay Estuary are dominated by runoff from the Central Valley catchment and remobilization of contaminated sediments deposited during past mining activities. The model suggests that the response time of mercury concentrations in the San Francisco Bay Estuary to changes in loadings is long, on the order of 50 years.

MacVean, L., and M. Stacey (2010). The influence of lateral exchange with perimeter habitat on the stratification and mixing of salt in a tidal channel. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
In this study we investigate the impacts of habitat restoration on the salinity dynamics of a tidal slough in the South San Francisco Bay. The Island Ponds, which are a cluster of three adjacent salt ponds, were breached to tidal action via Coyote Creek, a macro-tidal channel, in early 2006 as part of the South Bay Salt Pond Restoration project. We collected oceanographic data, such as flow velocities, salinities, and depths, in Coyote Creek and one of the Island Ponds (A21) in order to characterize the exchange between them and the influence of this exchange on the salt field of Coyote Creek. Our results indicate that interaction with the former salt ponds causes a drastic modification to the pattern of vertical mixing and density stratification that would normally be expected for a partially-mixed estuary. Instead of a stratified water column on ebb-tides, which is what estuarine theory predicts, we have observed well-mixed conditions on ebbs in Coyote Creek. We hypothesize that this is due to a particular sequence of events: the ponds temporarily trap water on each flood tide and release it out of phase with the main channel on the ebbs; the difference in phasing sets up cross-channel gradients in salinity; the flow through the breach on the ebbs strains the lateral salinity gradient, producing convective instabilities and energetic turbulent mixing. This pattern of stratification could have important implications for the recovering salt marsh. For example, the salinity of the water highest in the water column may determine the types of vegetation that establish at the upper elevations of the inter-tidal region. Under typical circumstances when the ebb tide is stably stratified, the freshest flows are able to reach the high marsh. However, if ebbs are well-mixed as we’ve observed, saltier water will be inundating this region.

MacWilliams, M. L. (2010). 3-D simulation of sea level rise for the Bay Delta Conservation Plan. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
As part of the Bay Delta Conservation Plan (BDCP) future conditions are being evaluated which will require accurate prediction of potential salinity impacts resulting from an increase in salinity intrusion into the Sacramento-San Joaquin Delta resulting from sea level rise. The three-dimensional UnTRIM Bay-Delta model was applied to estimate salinity impacts for a range of sea level rise scenarios. The UnTRIM Bay-Delta model was configured to run boundary conditions identical to those used in DSM2 to allow for detailed comparison of salinity intrusion as a function of sea level rise between the UnTRIM and DSM2 models. In order to parameterize the increased salinity intrusion predicted by the 3-D UnTRIM model into the 1-D DSM2 model, dispersion factors in DSM2 are being recalibrated to produce the level of salinity intrusion predicted by UnTRIM for each level of sea level rise simulated. This will allow for the incorporation of the effects of increased salt intrusion into the Delta resulting from sea level rise into the water operations models, such as CALSIM II. The predicted salinity increases resulting from increased salt intrusion into the Delta with increasing sea level rise demonstrate the potential range of expected increases in Delta salinity without operational changes. The 3-D sea level rise simulation results demonstrate that there are many different processes which result in salinity impacts with increasing sea level, including increased gravitational circulation, decreased efficiency of flushing flows, and a slower response in the south Delta to inflow salinity increases.

MacWilliams, M. L., W. Brostoff, and F. Wu (2010). An evaluation of the hydrodynamic and salinity impacts resulting from the deepening of the Sacramento Deep Water Ship Channel. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The U.S. Army Corps of Engineers is conducting a reevaluation study for deepening the Sacramento River navigation channel. The Sacramento project is a Limited Reevaluation Study which includes the evaluation of the hydrodynamic and salinity impacts of the proposed deepening of the Sacramento DWSC. Given concerns about increased salt intrusion into the Sacramento-San Joaquin Delta which may result from this deepening project, a three-dimensional hydrodynamic and salinity model was used to simulate salt intrusion under currently maintained conditions and under the proposed channel deepening alternatives under both existing and future conditions. The UnTRIM Bay-Delta model was used to simulate salt intrusion under the currently maintained DWSC configuration and under the a project alternative that entails the deepening of the Sacramento DWSC. In this analysis the Sacramento DWSC extending from Mile 0 near Collinsville to Mile 35 is deepened from 30 feet MLLW to 35 feet MLLW. Since the upstream reach from Mile 35 to the Port of Sacramento has already been deepened to a depth of 35 feet MLLW, no additional deepening of this reach was applied in this scenario. The predicted impact of the deepening of the Sacramento DWSC on stage, flow, and salinity in the Sacramento-San Joaquin Delta will be presented. The results show that the deepening of the Sacramento DWSC does not have an impact on salinity in the Sacramento-San Joaquin Delta during periods when X2 is less than 75 km. During late summer and fall conditions the Sacramento DWSC Deepening scenario results in increased salt intrusion along the Sacramento River between Collinsville and Rio Vista. The predicted impact of the deepening of the Sacramento DWSC deepening on X2 and the D-1641 water quality standards will be discussed.

MacWilliams, M. L. (2010). The need for speed: 3-D hydrodynamic and salinity simulations using the UnTRIM Bay-Delta Model. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The UnTRIM Bay-Delta model is a three-dimensional hydrodynamic and salinity model of San Francisco Bay and the Sacramento-San Joaquin Delta, which extends from the Pacific Ocean through the entire Sacramento-San Joaquin Delta. The UnTRIM Bay-Delta model has been used in studies of San Francisco Bay and the Sacramento-San Joaquin Delta for California DWR, USBR, USGS, and the US Army Corps of Engineers. The model calibration and validation conducted as part of these studies demonstrate that the UnTRIM Bay-Delta model is accurately predicting flow, stage, and salinity in San Francisco Bay and the Sacramento-San Joaquin Delta under a wide range of hydrologic conditions. Recent advances in processor, compiler, numerical, and grid generation technologies have resulted in significant speed-up of 3-D model simulations. The most recent version of the UnTRIM Bay-Delta model simulates 3-D hydrodynamics and salinity from the coastal ocean through all of San Francisco Bay and the Sacramento-San Joaquin Delta at more than 30 times real time on a single desktop workstation computer, allowing for feasible year-long simulations. However, future conditions simulations for the Delta which incorporate sea level rise, flooded islands, and marsh restoration may require even faster 3-D modeling tools. By specifying high resolution bathymetry on a coarser computational grid using a sub-grid approach developed by Vincenzo Casulli (Casulli, 2009), the tools now exist to develop even faster 3-D Delta models using UnTRIM. This presentation will focus on the salinity calibration results of the high resolution UnTRIM Bay-Delta model and present several applications which demonstrate the potential for even faster 3-D UnTRIM Bay-Delta model applications by applying the UnTRIM sub-grid approach to the San Francisco Bay-Delta. Preliminary results show that simulation of 3-D Bay-Delta hydrodynamics at speeds faster than 365 times real time or more on a single desktop workstation computer are feasible, and can provide accurate results.

Mager, R. C., S. I. Doroshov, et al. (2004). Early Life Stages of Delta Smelt. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 169-180.
Delta smelt Hypomesus transpacificus juveniles caught in the Sacramento-San

Joaquin Delta were reared in the laboratory to full sexual maturity, and embryos were obtained by in vitro fertilization and natural spawning in tanks. Duration of embryo development to hatching was 11-13 d at 14.8-16.0 degree C, with a development rate similar to other Hypomesus. Newly hatched larvae were 5.1-5.7 mm total length and resorbed the yolk sac within 6 d and lipid globule within 10 d. Exogenous feeding on rotifers started 5-6 d posthatch. Delta smelt have indirect development with a prolonged larval phase prior to juvenile metamorphosis. Fin differentiation began at 10-12 mm, 20-30 d posthatch, and was completed at 19-20 mm and 50-60 d, concomitant with swim bladder inflation. Metamorphosis was completed in 120 d when juveniles were about 35 mm total length. The prolonged larva fin fold stage lacking a functional swim bladder may be an adaptation to passively use water currents in estuarine nursery areas.

Maher, K. (2010). Precipitation in the San Francisco Bay Watershed, Water Years 2008 and 2009. IEP Newsletter. 23: 2.

Malamud-Roam, F., M. Dettinger, et al. (2007). "Holocene Climates and Connections between the San Francisco Bay Estuary and its Watershed: A Review " San Francisco Estuary and Watershed Science 5(1): Article 3.
Climate over the watershed of the San Francisco Bay Delta estuary system varies on a wide range of space and time scales, and affects downstream estuarine ecosystems. The historical climate has included mild to severe droughts and torrential rains accompanied by flooding, providing important lessons for present-day resource managers. Paleoclimate records spanning the last 10,000 years, synthesized across the Estuary, watershed and key regions beyond, provide a basis for increased understanding of how variable California’s climate can be and how it affects the Bay Delta system.

This review of paleoclimate records reveals a gradual warming and drying in California from about 10,000 years to about 4,000 years before present. During this period, the current Bay and Delta were inundated by rising sea level so that by 4,000 years ago the Bay and Delta had taken on much of their present shape and extent. Between about 4,000 and 2,000 years ago, cooler and wetter conditions prevailed in the watershed, lowering salinity in the Estuary and altering local ecosystems. Those wetter conditions gave way to increasing aridity during the past 2,000 years, a general trend punctuated by occasional prolonged and severe droughts and occasional unusually wet, cool periods. California’s climate since A.D. 1850 has been unusually stable and benign, compared to climate variations during the previous 2,000 or more years. Thus, climate variations in California’s future may be even more (perhaps much more) challenging than those of the past 100 years. To improve our understanding of these past examples of climate variability in California, and of the linkages between watershed climate and estuarine responses, greater emphases on paleoclimate records in and around the Estuary, improved temporal resolutions in several record types, and linked watershed-estuary paleo-modeling capabilities are needed.

Malamud-Roam, F. and B. L. Ingram (2001). "Carbon Isotopic Compositions of Plants and Sediments of Tide Marshes in the San Francisco Estuary." Journal of Coastal Research 17(1): 17-29.
Wetland sediments surrounding the San Francisco Bay Estuary contain a rich history of environmental change which can aid predictions of potential responses to future environmental change. Here we present results of a study of the stable carbon isotopic composition of modern surface sediments as they relate to the existing plant cover. The results indicate a strong correlation between the modern plant cover and the delta super(13)C value of underlying surface sediments (RMS = 1.331). Reasons for residual differences between predicted and observed isotopic values of the surface soils include intraspecific changes in delta super(13)C values of C3 plants, contributions to the carbon pool by algae, and effects of diagenesis on delta super(13)C value of plant matter. The goal of this research is to provide a basis for interpreting isotopic data obtained from sediment cores in terms of changes in vegetation resulting from changes in environmental conditions.

Malamud-Roam, F. and B. Lynn Ingram (2004). "Late Holocene delta super(1) super(3)C

and pollen records of paleosalinity from tidal marshes in the San Francisco Bay estuary, California." Quaternary Research 62(2): 134-145.
Records of stable carbon isotopes (delta super(1) super(3)C) are presented from cores collected from four San Francisco Bay marshes and used as a proxy for changes in estuary salinity. The delta super(1) super(3)C value of organic marsh sediments are a reflection of the relative proportion of C sub(3) vs. C sub(4) plants occupying the surface, and can thus be used as a proxy for vegetation change on the marsh surface. The four marshes included in this study are located along a natural salinity gradient that exists in the San Francisco Bay, and records of vegetation change at all four sites can be used to infer changes in overall estuary paleosalinity. The delta super(1) super(3)C values complement pollen data from the same marsh sites producing a paleoclimate record for the late Holocene period in the San Francisco Bay estuary. The data indicate that there have been periods of higher-than-average salinity in the Bay estuary (reduced fresh water inflow), including 1600-1300 cal yr B.P., 1000-800 cal yr B.P., 300-200 cal yr B.P., and ca. A.D. 1950 to the present. Periods of lower-than-average salinity (increased fresh water inflow) occurred before 2000 cal yr B.P., from 1300 to 1200 cal yr B.P. and ca. 150 cal yr B.P. to A.D. 1950. A comparison of the timing of these events with records from the California coast, watershed, and beyond the larger drainage of the Bay reveals that the paleosalinity variations reflected regional precipitation.

Malamud-Roam, F. P., B. L. Ingram, et al. (2006). "Holocene paleoclimate records from a large California estuarine system and its watershed region: linking watershed climate and bay conditions." Quaternary Science Reviews 25(13-14): 1570-1598.
The San Francisco Bay-Delta system includes a watershed that covers a large area of California and provides water to two-thirds of the State's population. Climate over the estuary and its watershed in the dry summer months is controlled by the subtropical high which dominates and deflects storms from California. The subtropical high weakens and migrates south as the Aleutian Low strengthens, bringing wet winter storms to the region. Paleoclimatic records from the Bay and its greater watershed, spanning the Holocene, are reviewed here in order to better understand natural variations of precipitation and runoff and the linkages between those variations and the salinity and ecosystems of the estuary. To better understand regional-scale climate patterns, paleoclimate records from coastal California and the Great Basin are also considered. Large fluctuations in climate have occurred during the period of interest, and there is generally good agreement between the paleoclimate records from different regions. Early Holocene climate throughout California was marked by rising temperatures and reduced moisture as seen in fire records from the watershed. This warmth and aridity peaked about 5000-7000 years ago and was followed by a cooling trend, with variable moisture conditions. The Estuary formed relatively rapidly in response to a high rate of sea level rise that dominated the Holocene until about 6000 years ago, and the subsequent reduced rate of inundation allowed vast tidal marshes to form along the edges of the estuary, which have since been recording changes in environmental conditions. The impacts of changing regional climate patterns are experienced in the San Francisco Bay-Delta system, as altered fresh water flows result in altered estuary salinity. For example, approximately 3800 cal yr B.P., records from throughout the state indicate a cool, moist period, and Bay salinity was reduced; this period was followed by a general drying trend throughout California over the last two millennia, punctuated by decades to centuries-long droughts and brief, extremely wet events. In particular, during the period ca. 1000-800 cal yr B.P. (A.D. 950-1150) conditions seem to have been unusually dry in many parts of the watershed, reducing the fresh water flows to the estuary, and shifting tidal marsh plant assemblages toward less diverse, but more salt-tolerant plants. In contrast, the Little lee Age (ca. 550-200 cal yr B.P.) brought unusually cool and wet conditions to much of the watershed, and lowered salinity in the Bay. Many reconstructions suggest that notably stable conditions have prevailed over the instrumental period, i.e., after ca. A.D. 1850, even including the severe, short-term anomalies experienced during this period. Interdecadal variability is common in many of the records, with timescales of ca. 55, 70, 90, 100, 150, and 200 years. (c) 2006 Elsevier Ltd. All rights reserved.

Malamud-Roam, K. (2000). Tidal regimes and tide marsh hydroperiod in the San

Francisco Estuary: theory and implications for ecological restoration, University of California, Berkeley.

Manly, B. F. J. and M. A. Chotkowski (2006). "Two new methods for Regime Change Analyses." Archiv für Hydrobiologie 167(1-4): 593-607.
        There is currently a good deal of concern about a recently recognized decline in the numbers of several pelagic fish species in the Sacramento-San Joaquin Delta in California, USA. Several research groups are investigating possible reasons for this decline. One part of this study addresses whether the decline is the result of some recent regime change in the ecosystem, and more generally whether one or more regime changes have occurred since regular sampling of fish, zooplankton and mysids shrimps began in 1967. There are many statistical methods of analysis that have been proposed to detect regime changes. These are reviewed, but it is noted that none of them is immediately suitable for analysing the basic data collected from the Sacramento-San Joaquin Delta, which consists of counts from trawl hauls and other sampling gears used in the field. Two new methods are therefore proposed for this type of data, which is commonly collected. One method searches for times when the mean level and trend in the abundance of an organism changed, assuming that in the absence of a regime change the abundances will exhibit a linear trend with time. The other method assumes that in the absence of a regime change the abundances will exhibit a polynomial trend in time, and searches for times when the mean level changed significantly. Both methods rely on bootstrap resampling of the data for assessing the significance of apparent regime changes. Simulation studies to verify the properties of the proposed analyses are described, and also some examples of the results of the analyses on the Sacramento-San Joaquin data.

Marchetti, M. (1999). Ecological Effects of Non-native Fish Species in Low Elevation Streams of the Central Valley, California, University of California at Davis.
        Three separate studies are described which examine the effects of non-native fish species on Central Valley California streams. The first is an experimental study of competition between a California native centrarchid, the Sacramento perch (Archoplites interruptus) and an ubiquitous non-native, the bluegill (Lepomis macrochirus). The experiments indicate that (1) Sacramento perch gain less weight and show reduced growth when placed with bluegill, (2) Sacramento perch demonstrate less aggressive behavior than bluegill, (3) Sacramento perch shift their habitat use in the presence of bluegill. Overall the results imply that Sacramento perch and bluegill exhibit interspecific competition. The second work is an investigation into the larval ecology of stream fish in Putah Creek, a Central Valley stream. Native larvae occurred both earlier in the year and in higher abundance than introduced species. Both native larvae and overall numbers of larvae were more abundant at the upstream site. Larval fish abundance was not a good indicator of juvenile abundance at the same sites later in the year. The two methods of collection utilized tended to select for different species. At both locations larval fish were collected in significantly greater numbers at night. It is suggested that the difference between the sites is due to habitat changes resulting from an upstream dam that has created a refuge for native taxa.

Marchetti, M., M. Limm, R. Walther, G.M. Benigno, and H. Bowen (2010). Critical role of seasonal tributaries for native fish and aquatic biota in the Sacramento River. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
        Due to the Central Valley’s Mediterranean climate, the Sacramento River has an abundance of small tributaries that contain water only during the winter/spring wet season. Over the past 8 years we examined the ecology of these tributaries in terms of native fishes and aquatic macroinvertebrates and will highlight the critical role this underappreciated habitat plays in the overall functioning of the entire riverine ecosystem. In this talk I discuss and summarize data from five individual studies examining ecological aspects of this habitat. In a study of juvenile Chinook growth in seasonal tributaries using otolith microstructure we find that fish grow bigger and faster on the abundant food and warmer temperatures in seasonal tributaries. In a four-year study on the spatial distribution and abundance of native fish larvae in tributaries of the upper Sacramento River we find that certain critical tributaries (Mud Creek) produce almost an order of magnitude

more native fish larvae than nearby permanent streams. In a study comparing the distribution and abundance of aquatic macroinvertebrates in a seasonal tributary with a nearby permanent stream we find the seasonal tributary contains unique taxa as well as higher drift densities and an ecologically distinct community. In a cross-watershed comparison of larval fish drift density we find that a seasonal tributary (Mud Creek) produces more larvae on a per volume basis than all other streams/rivers we examined. In a comparison of juvenile Chinook growth morphology between seasonal and permanent streams using geometric morphometrics we find that salmon growth is characteristically different in seasonal tributaries, possibly leading to a better and healthier fish morphology. Taken together, this extensive body of work highlights the critical importance of this habitat and strongly suggests the need for watershed conservation directed at this neglected aspect of Central Valley stream ecology.

Marchetti, M. P. (1999). "An Experimental Study of Competition Between the Native Sacramento Perch (Archoplites interruptus) and Introduced Bluegill (Lepomis macrochirus)." Biological Invasions 1(1): 55-65.

The Sacramento perch (Archoplites interruptus), a sunfish (Centrarchidae) native only to the Central Valley of California, has been eliminated from most of its native range. To examine the role of interspecific competition in this decline, a series of experiments were conducted to assess the growth, aggressive behavior, and habitat use of Sacramento perch in the presence of bluegill (Lepomis macrochirus), an introduced centrarchid. The experiments indicate that (1) Sacramento perch gain less weight and show reduced growth when placed with bluegill, but that this interaction only occurs with food limitation, and is not affected by overall fish density; (2) Sacramento perch demonstrate less aggressive behavior than bluegill, but become more aggressive when they are conspicuously larger than bluegill; (3) Sacramento perch shift their habitat use in the presence of bluegill. Overall the results imply that Sacramento perch and bluegill exhibit interspecific competition where the mechanism of interaction is aggressive dominance by bluegill. It is suggested that long term persistence of Sacramento perch may require a habitat that is free of introduced centrarchid fishes, or one controlled by a naturally variable hydrological regime.

Marchetti, M. P., E. Esteban, et al. (2004). Evaluating Aspects of Larval Light Trap Bias and Specificity in the Northern Sacramento River System: Do Size and Color Matter? Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 269-279.

Light traps have been used to study the distribution and ecology of fish larvae in a variety of waters. Yet the physical and taxonomic limitations of light traps have been little studied, particularly in lotic systems. The purpose of this study was to examine aspects of light trap use, bias, and specificity in a natural stream setting. We sampled fish larvae using light traps in the upper Sacramento River watershed in April (2001, 2002) and June (2002) using five different color light sources and two trap sizes. Our results suggest that (1) small traps are as effective at sampling fish larvae as large traps, (2) color of light and/or relative intensity of light have strong effects on numbers of larvae collected, and (3) environmental factors play a role in the number of larvae collected over short time periods.

Marchetti, M. P., T. Light, et al. (2004). "Fish invasions in California watersheds: Testing hypotheses using landscape patterns." Ecological Applications 14(5): 1507-1525.

An important goal of invasion biology is to identify physical and environmental characteristics that may make a region particularly receptive to invasions. The inland waters of California (USA) are highly invaded, particularly by fishes, although there is wide variation in numbers of normative fishes across the state's watersheds. Here we examine patterns of fish invasions in California watersheds and their associations with natural environmental characteristics, native fish diversity, and various measures of human habitat disturbance. Our analysis is based on an extensive data set on the distribution of freshwater fishes across California's watersheds and on GIS land-use coverages for the entire state. We used canonical correspondence analysis to examine associations between environmental characteristics and the distributions of both native and normative fish species. We then employed an information-theoretic model-selection approach to rank hypothesized models derived from the fish invasion literature with regard to how well they predicted numbers of normative fishes in California watersheds. Our results indicate that pervasive, anthropogenic, landscape-level changes (particularly the extent of urban development, small-scale water diversions, aqueducts, and agriculture) influenced spatial patterns of invasion. In addition, we find that deliberately stocked fishes have different habitat associations, including a strong association with the presence of dams, than other introduced fishes. In our analysis, watersheds with the most native species also contain the most normative species. We find no evidence that existing watershed protection helps to prevent fish invasions in California, but we suggest that restoration of natural hydrologic processes may reduce invasion impacts.

Marchetti, M. P., J. L. Lockwood, et al. (2006). "Effects of urbanization on California's fish diversity: Differentiation, homogenization and the influence of spatial scale." Biological Conservation 127(3): 310-318.

Human development of freshwater ecosystems has lead to drastic changes in freshwater fish faunas, including the loss of many native species and the gain of non-natives. Typically conservation ecologists view these two opposing forces as contributing to biological homogenization, and consider homogenization as one of the principle negative consequences of urbanization. However, homogenization is only one outcome out of many that can result from the loss and gain of species. In particular, it is possible for invasions and extinctions to lead to differentiation; a process whereby two (or more) regions become less similar to one another through time. Using the freshwater fishes of California, we show that urbanization is highly positively correlated to both the endangerment of native fish and the invasion of non-native fish within watersheds. Despite this, the fish faunas of California's watersheds have differentiated from one another through time. Furthermore, the degree of differentiation is positively correlated with measures of urbanization, which is contrary to expectation. We suggest that this result reflects: (1) the haphazard manner in which non-native fishes have been introduced into California watersheds, (2) the difficulty that both native and non-native fishes have in expanding their geographical ranges, and (3) the continued presence of vestiges of formerly distinct regional faunas. This pattern of differentiation among watersheds is likely a matter of scale, as previous work on freshwater fishes has demonstrated homogenization at both larger and smaller spatial scales. In addition the observed pattern is probably a short-term (temporal) phenomena and will disappear with continued invasion and extinction. We suggest that similar patterns may occur for other taxa that have limited natural dispersal abilities and that are idiosyncratically released as non-natives via human activities (e.g. herptiles). (c) 2005 Elsevier Ltd. All rights reserved.

Marchetti, M. P. and P. B. Moyle (2001). "Effects of flow regime on fish assemblages in a regulated California stream." Ecological Applications 11(2): 530-539.

The fishes in Lower Putah Creek, a regulated stream in the Central Valley of California, were sampled over a 5-yr period, 1994-1998. Distinct fish assemblages were observed in the lower 37 km of stream using two-way indicator species analysis (TWINSPAN) and canonical correspondence analysis (CCA). The assemblages segregated in an upstream-to-downstream manner. Distinct differences were found between assemblages of native and nonnative fishes and their association with environmental variables and habitat use. Native fishes tended to cluster in areas with colder temperatures, lower conductivity, less pool habitat, faster streamflow, and more shaded stream surface. Numbers of nonnative fish were negatively correlated with increased streamflow, and numbers of native fish were positively correlated with increased flow. Hydrologic variability between years and seasons indicated that flow regime had a large effect on the fish assemblages. This study provides a clear demonstration of how native fishes in streams of the western United States exhibit different habitat requirements and respond to temporal variation in flow in a different manner than nonnative fishes. It supports the concept that restoration of natural flow regimes, in company with other restoration measures, is necessary if the continued downward decline of native fish populations in the western United

States is to be reversed.

Marchetti, M. P., P. B. Moyle, et al. (2004). "Alien fishes in California watersheds: Characteristics of successful and failed invaders." Ecological Applications 14(2): 587-596.

The literature on alien animal invaders focuses largely on successful invasions over broad geographic scales and rarely examines failed invasions. As a result, it is difficult to make predictions about which species are likely to become successful invaders or which environments are likely to be most susceptible to invasion. To address these issues, we developed a data set on fish invasions in watersheds throughout California (USA) that includes failed introductions. Our data set includes information from three stages of the invasion process (establishment, spread, and integration). We define seven categorical predictor variables (trophic status, size of native range, parental care, maximum adult size, physiological tolerance, distance from nearest native source, and propagule pressure) and one continuous predictor variable (prior invasion success) for all introduced species. Using an information-theoretic approach we evaluate 45 separate hypotheses derived from the invasion literature over these three stages of the invasion process. Our results indicate that successful establishment is best predicted with our global model that includes all seven variables, suggesting an inherent multivariate nature to the establishment stage of the invasion process. Spread of introduced fishes is best predicted using measures of physiological tolerance and propagule pressure. Species integration and impact is best predicted using a measure of prior invasion success. The results from analyses like this will help guide and inform management decisions regarding current and future species introductions.

Marchetti, M. P., P. B. Moyle, et al. (2004). "Invasive species profiling? Exploring the characteristics of non-native fishes across invasion stages in California." Freshwater Biology 49(5): 646-661.

1. The global spread of non-native species is a major concern for ecologists, particularly in regards to aquatic systems. Predicting the characteristics of successful invaders has been a goal of invasion biology for decades. Quantitative analysis of species characteristics may allow invasive species profiling and assist the development of risk assessment strategies. 2. In the current analysis we developed a data base on fish invasions in catchments throughout California that distinguishes among the establishment, spread and integration stages of the invasion process, and separates social and biological factors related to invasion success. 3. Using Akaike's information criteria (AIC), logistic and multiple regression models, we show suites of biological variables, which are important in predicting establishment (parental care and physiological tolerance), spread (life span, distance from nearest native source and trophic status) and abundance (maximum size, physiological tolerance and distance from nearest native source). Two variables indicating human interest in a species (propagule pressure and prior invasion success) are predictors of successful establishment and prior invasion success is a predictor of spread and integration. 4. Despite the idiosyncratic nature of the invasion process, our results suggest some assistance in the search for characteristics of fish species that successfully transition between invasion stages.

Marchi, A., R. Dugdale, K. Taberski, A. Parker, C. Buck, and F. Wilkerson (2010). Spring 2010 phytoplankton blooms in northern San Francisco Estuary: Influences of climate and nutrients. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Low primary production and chlorophyll biomass has characterized the northern San Francisco Estuary (SFE) for the past three decades and have been linked to significant declines in higher order pelagic organisms within this ecosystem. Declines have been attributed to climate shifts, invasive species, and changes in nutrient loading. Our previous research indicates that the form of nitrogen making up the dissolved inorganic nitrogen (DIN) pool for phytoplankton growth can determine phytoplankton biomass accumulation and community structure; with high levels of ammonium in SFE inhibiting phytoplankton nitrate uptake, leading to low levels of primary production. During the anomalously wet year (2010), precipitation events occurred late into the spring period, and phytoplankton blooms were observed within the northern SFE. Here we describe phytoplankton bloom events occurring in Suisun Bay during April and May 2010 based on six samplings of seven stations distributed just upstream, just downstream and within Suisun Bay. Extracted chlorophyll values up to 30 µg/L were recorded in Suisun Bay in mid-April, and remained elevated 2 weeks later. Maximal chlorophyll values (~ 35 µg/L) were measured into late May, with Suisun Bay and adjacent Grizzly Bay averaging in excess of 27 µg/L. The 2010 bloom was enabled when the ammonium concentration fell to below 4 µM, and rapid phytoplankton biomass increases followed a measured nitrate drawdown. Additionally, salinity was low in the high chlorophyll locations. These two conditions, low ammonium and low salinity were key features in the only other spring bloom we have observed in Suisun Bay (in 2000). Knowledge gained by studying nutrient inputs and phytoplankton community structures, will provide a base for understanding the relationship between primary, secondary, and top producers in the SFE.

Marine, K. R. and J. J. Cech (2004). "Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon." North American Journal of Fisheries Management 24(1): 198-210.
Intensive water management and frequent drought cycles can increase water temperatures, thereby decreasing habitat quality for Chinook salmon Oncorhynchus tshawytscha inhabiting streams of California's Central Valley. We studied the incremental effects of chronic exposure (>60 d; effects measured bimonthly) to three temperature regimes typical of the range of conditions experienced by Sacramento River fall-run Chinook salmon during juvenile rearing and smoltification (13-16 degree C, 17-20 degree C, and 21-24 degree C; diel fluctuations of 0.5-3 degree C were allowed within these limits). Our laboratory experiments demonstrated that Chinook salmon can readily survive and grow at temperatures up to 24 degree C. However, juveniles reared at 21-24 degree C experienced significantly decreased growth rates, impaired smoltification indices, and increased predation vulnerability compared with juveniles reared at 13- 16 degree C. Fish reared at 17-20 degree C experienced similar growth, variable smoltification impairment, and higher predation vulnerability compared with fish reared at 13-16 degree C. These results improve our understanding of the range of juvenile Chinook salmon responses to elevated temperatures and should assist biologists and resource decision makers in coordinating water management and salmon conservation decisions.

Markiewicz, D., L. Deanovic, J. Khamphanh, and I. Werner (2010). Sensitivity comparison of indigenous species to standard model species of fish and invertebrates. IEP 2010 Annual Workshop and the 6th Biennial Bay–Delta Science Conference. Poster paper presented at the California State University, Sacramento and the Sacramento Convention Center, Sacramento, CA.
Surface water quality and ecosystem structure are affected by a vast number of contaminants introduced to the system from a multitude of sources. California State’s freshwater streams and estuaries provide habitats for countless species of wildlife and sensitivity to aquatic contaminants varies significantly between organisms. The Aquatic Toxicology Laboratory at UC Davis has developed toxicity test protocols for two native species: the amphipod Hyalella azteca and the delta smelt (Hypomesus transpacificus), and have performed comparative tests alongside the cladoceran Ceriodaphnia dubia and the fathead minnow (Pimephales promelas), commonly used as standard test organisms. Comparative tests were conducted between the amphipod and cladoceran species, and between both species of fish, on exposures to copper, ammonia, organophosphate insecticides, and pyrethroid insecticides, in 96-h water column tests. H. azteca was less sensitive to copper and organophosphates, but more sensitive to pyrethroids, than C. dubia. Given the decline in the use of organophosphates and the increased use of pyrethroids, the use of H. azteca toxicity testing is expected to improve the detection of pesticide contamination relative to C. dubia. Heightened pyrethroid sensitivity and tolerance to a wide range of salinity make H. azteca a promising species for testing Bay-Delta fresh to brackish water quality. P. promelas was more sensitive to bifenthrin and permethrin, while H. transpacificus was more sensitive to cyfluthrin and the other six toxicants tested. Reliance on P. promelas tests therefore underestimates toxicity of copper, ammonia and organophosphate insecticides to H. transpacificus. Our results suggest that in order to accurately monitor contaminant toxicity in Bay-Delta waters it is

important to first investigate inter-species sensitivity, utilizing a suite of organisms native to the area of study, in conjunction with EPA approved standard test organisms.

Markmann, C. (1986). "Benthic monitoring in the Sacramento-San Joaquin Delta: results from 1975 through 1981. IESP (Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary) Technical Report 24: 51 pp., & app."

Marsh, G. (2007). "Historic and Present Distribution of Chinook Salmon and Steelhead in the Calaveras River " San Francisco Estuary and Watershed Science 5(3): Article 3.

Interest is great in projects that would restore Central Valley steelhead (Oncorhynchus mykiss) and Central Valley Chinook salmon (Oncorhynchus tshawytscha) to California drainages where they have historically existed and where there is good quality habitat upstream of instream barriers. The Calaveras River has garnered renewed attention for its potential to support these anadromous fish. I evaluated migration opportunity in the Calaveras River, and whether these salmonids could have been present in the river historically, by comparing historical anecdotal and documented observations of Chinook salmon and steelhead to recorded flows in the river and Mormon Slough, the primary migration corridors. Collected data show that these fish used the river before New Hogan Dam was constructed in 1964. Three different Central Valley Chinook salmon runs, including fall-, late-fall- and spring-run salmon, and steelhead may have used the river before the construction of New Hogan Dam. Fall and possibly winter run and steelhead used the river after dam construction. The timing and amount of flows in the Calaveras River, both before and after the construction of New Hogan Dam, provided ample opportunity for salmonids to migrate up the river in the fall, winter, and spring seasons when they were observed. Flows less than 2.8 m3/s (100 ft3/s) can attract fish into the lower river channel and this was likely the case in the past, as well. Even in dry years of the past, flows in the river exceeded 5.6 m3/s (200 ft3/s), enough for fish to migrate and spawn. Today, instream barriers and river regulation, which reduced the number of high flow events, has led to fewer opportunities for salmon to enter the river and move upstream to spawning areas even though upstream spawning conditions are still adequate. Improving migration conditions would allow salmonids to utilize upstream spawning areas once again.

Marshack, J., K. Larsen, and V. Connor (2010).
The California Water Quality Monitoring Council. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Marshack, J., K. Larsen, V. Connor, and J. Kapellas (2010).
Using web portals to present meaningful information. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Marshack, J. B. (2011). A Compilation of Water Quality Goals.

This State Water Resources Control Board (State Water Board) staff report, A Compilation of Water
Quality Goals, supersedes the July 2008 edition published by the Central Valley Regional Water
Quality Control Board and all other editions and updates published prior to July 2008. Earlier editions
and updates should be discarded, as they contain outdated information. This edition includes an online
searchable database of water quality based numeric thresholds available at http://www.waterboards.ca.gov/ water_issues/programs/water_quality_goals/.

The text of this edition has been updated and expanded to include tools to aid in the selection of
assessment thresholds for marine and estuarine waters, in addition to similar tools provided in earlier
editions for groundwater and inland surface waters. The online database contains

up-to-date numeric
thresholds from a variety of sources, including:
♦ California and Federal Drinking Water Standards (MCLs)
♦ California Public Health Goals (PHGs)
♦ California State Notification and Response Levels for Drinking Water
♦ Health Advisories, Water Quality Advisories, and Drinking Water Advisories
♦ Suggested No-Adverse-Response Levels (SNARLs)
♦ Cancer Risk Estimates
♦ Health-based criteria from USEPA's Integrated Risk Information System (IRIS)
♦ Proposition 65 Safe Harbor Levels
♦ California Toxics Rule and National Toxics Rule Criteria to Protect Human Health and Aquatic
Life
♦ California Ocean Plan Water Quality Objectives
♦ U.S. Environmental Protection Agency (USEPA) Recommended Criteria to Protect Human

Health and Aquatic Life
♦ Agricultural Use Protective Thresholds
♦ Taste and Odor Based Criteria

The narrative Selecting Water Quality Goals contains information to help users to understand
California’s water quality standards adopted to protect the beneficial uses of surface water and
groundwater resources, available criteria and guidance for evaluating water quality, and to help users
select defensible numeric assessment thresholds based on applicable water quality standards.
To use this information correctly, it is necessary to read Selecting Water Quality Goals carefully
before using numeric thresholds from the database.

Water Quality Goals is a technical report prepared by staff of the State Water Board. It is intended to
help identify and assess potential water quality concerns. This report is an informational tool only and
does not establish State Water Board policy or regulation. The information presented in this report is
not binding on any person or entity, nor does it represent final action of the State Water Board or any
Regional Water Board. This report is not intended, nor can it be relied upon, to create any rights
enforceable by any party in litigation in the State of California. The overseeing regulatory authority may
decide to use the information provided herein, or t

Martin, M. A., J. P. Fram, et al. (2007). "Seasonal chlorophyll a fluxes between the coastal Pacific Ocean and San Francisco Bay." Marine Ecology Progress Series 337: 51-61.
We measured chlorophyll a (chl a) fluxes between San Francisco Bay and the coastal
ocean for 2 d in March 2002, October and November 2002, and June 2003; 1 d during neap tide and
1 d during spring tide. We applied harmonic analysis to velocity and chl a data to model scalar and
velocity fields during a spring–neap cycle. We then integrated these data over the fortnightly period
to calculate net dispersive fluxes. The net flux consisted of an advective and dispersive component.
Dispersive flux was decomposed into physical mechanisms such as tidal pumping, steady circulation
and unsteady circulation. Net flux was large and directed out of San Francisco Bay during spring,

large and into the estuary during summer, and effectively zero during fall surveys. The direction of
advective flux was always out of the estuary and the magnitude depended on advective speed and
mean chl a concentration. Dispersive flux was of a similar magnitude to advective flux each season
and changed direction seasonally. Based on historical records and simultaneous observations, we
conclude the reversal of the dispersive flux is most likely due to difference in phytoplankton growth
conditions (or difference in timing of blooms) in the coastal ocean and estuary. During the spring,
phytoplankton bloom in the estuary, creating a net seaward flux. In summer, during upwelling,
phytoplankton bloom in the coastal ocean, driving a net flux into the estuary. Tidal pumping
accounted for 79% of spring, 63% of fall and 93% of summer dispersive flux. Steady fluxes were
about 1 order of magnitude smaller than tidal pumping, and unsteady fluxes yet another 1 order
of magnitude smaller. The dominance of tidal pumping implies that seasonal variability of ocean-
estuary exchange is set almost entirely by variation in the gradient of chl a concentrations between
the ocean and the estuary such that the variability of ocean-estuary exchange is set by variation in
the occurrence of estuarine and oceanic blooms.

Martin, R., R. Burmester, and D. Threloff (2010). The Anadromous Fish Restoration Program, a status update. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The Central Valley Project Improvement Act (CVPIA) directs the Secretary of the Interior to develop and implement a program that makes all reasonable efforts to double natural production of anadromous fish in Central Valley streams. The program is known as the Anadromous Fish Restoration Program (AFRP). Species of anadromous fish to be restored under the AFRP include Chinook salmon, steelhead, striped bass, American shad, and white and green sturgeon. The AFRP is an opportunity for the U.S. Fish and Wildlife Service and the Bureau of Reclamation to collaborate with other agencies, organizations and the public to increase natural production of anadromous fish in Central Valley streams by augmenting and assisting restoration efforts presently conducted by local watershed workgroups, the California Department of Fish and Game (CDFG), and others. The Final Restoration Plan is a comprehensive approach to doubling anadromous fish populations in Central Valley streams. The plan documents restoration goals, objectives, project implementation strategies, describes restoration actions and evaluations, project prioritizations, monitoring, and adaptive management. The AFRP has observed significant changes in the average natural production of fall run Chinook salmon between the 1967-1991 and 1992-2009 time periods in six watersheds ($p < 0.05$) and has met the doubling goal in Butte, Battle, and Clear creeks. The AFRP average natural production for late fall Chinook salmon increased in Battle Creek but decreased in the Sacramento River ($p < 0.05$). Spring run Chinook salmon in Butte Creek increased significantly from the 1967-1991 baseline period ($p < 0.05$) but decreased in the Sacramento River. Winter run in the Sacramento River has also seen a significant decrease from the baseline period ($p < 0.05$). The AFRP is currently 14%, 83%, and 1% below the baseline average (1967-1991) for all races of Chinook salmon, steelhead, and white sturgeon respectively. The AFRP Chinook salmon natural production average has been decreasing in the last couple of years due to low adult escapement estimates resulting from poor ocean returns.

Marvin DiPasquale, M. C., J. L. Agee, et al. (2003). "Microbial cycling of mercury in contaminated pelagic and wetland sediments of San Pablo Bay, California." Environmental Geology 43(3): 260-267.

San Pablo Bay is an estuary, within northern San Francisco Bay, containing

elevated sediment mercury (Hg) levels because of historic loading of hydraulic mining debris during the California gold-rush of the late 1800s. A preliminary investigation of benthic microbial Hg cycling was conducted in surface sediment (0-4 cm) collected from one salt-marsh and three open-water sites. A deeper profile (0-26 cm) was evaluated at one of the open-water locations. Radiolabeled model Hg-compounds were used to measure rates of both methylmercury (MeHg) production and degradation by bacteria. While all sites and depths had similar total-Hg concentrations (0.3-0.6 ppm), and geochemical signatures of mining debris (as epsilon Nd, range: -3.08 to -4.37), in-situ MeHg was highest in the marsh (5.4 plus or minus 3.5 ppb) and less than or equal to 0.7 ppb in all open-water sites. Microbial MeHg production (potential rate) in 0-4 surface sediments was also highest in the marsh (3.1 ng g super(-1) wet sediment day super(-1)) and below detection (<0.06 ng g super(-1) wet sediment day super(-1)) in open-water locations. The marsh exhibited a methylation /demethylation (M/D) ratio more than 25 x that of all open-water locations. Only below the surface 0-4-cm horizon was significant MeHg production potential evident in the open-water sediment profile (0.2-1.1 ng g super(-1) wet sediment day super(-1)). In-situ Hg methylation rates, calculated from radiotracer rate constants, and in-situ inorganic Hg(II) concentrations compared well with potential rates. However, similarly calculated in-situ rates of MeHg degradation were much lower than potential rates. These preliminary data indicate that wetlands surrounding San Pablo Bay represent important zones of MeHg production, more so than similarly Hg-contaminated adjacent open-water areas. This has significant implications for this and other Hg-impacted systems, where wetland expansion is currently planned.

Maslin, P. E., M. Lennox, et al. (1997). Intermittent streams as rearing habitat for Sacramento River chinook salmon (Oncorhynchus tshawytscha).
This study documents nonnatal rearing of juvenile chinook in several intermittent tributaries to the Sacramento River. Condition factors and length measurements of juvenile chinook salmon captured in the intermittent tributaries were compared with those of juvenile chinook captured in the mainstem Sacramento River. The data suggests that juvenile chinook rearing in the tributaries grew faster and were heavier for their length than those rearing in the mainstem. Faster growing fish smolt earlier, and may enter the Delta earlier in the year, before low water and pumping degrade rearing habitat. Optimal rearing conditions in the tributaries exist from approximately December through March. By April, conditions may be less favorable as temperatures rise and piscivorous fishes enter tributaries to spawn. Juvenile chinook entering the tributaries earliest in the year, such as winter and spring run, probably derive the most benefit from tributary rearing. Fall run, and especially late fall run, may be exposed to warmer than optimal temperatures, predation, and stranding.

Massoudieh, A., E. Loboschefsky, et al. (2011). "Spatio-temporal modeling of striped-bass egg, larval movement, and fate in the San Francisco Bay-Delta." Ecological Modelling 222(19): 3513-3523.

Matella, M., and J. Cain (2010). Scenarios for restoring ecologically functional floodplains and providing ecosystem services in the Sacramento-San Joaquin Delta. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
California’s Central Valley was once a large dynamic river-floodplain system that flooded seasonally, creating heterogeneous habitat supporting biodiversity. Over the last century, dams and levees have severed hydraulic connections between river channels and their floodplains by containing floodwaters between levees or in reservoirs. The State of California has embarked on the development of a new flood plan for the Central Valley that could either perpetuate the loss of inundated floodplain habitat or substantially restore it. Ideally, new flood management projects could be designed with the dual goals of lowering flood stage during extreme flood events, but also increasing the wetted surface area during regular high flow events. The overall goal of our research is to develop a geo-spatial method for determining where levee setbacks and bypasses could be located to optimize flood risk reduction, water supply, and ecological benefits. We used a coarse scale spatial analysis that is based on a synthesis of high-resolution

spatial and hydrologic data to identify where functional floodplain recovery, water supply enhancement, and flood protection might coincide and thereby prioritize locations for promising multi-purpose floodplain restoration projects across the entire valley with a focus on the Sacramento-San Joaquin Delta. In the South Delta, the Hydrologic Engineering Center-Ecosystems Functions Model (HEC-EFM) was used to simulate potential future changes in the extent of inundation and resulting ecological benefit. The end product of our approach is a template for developing multiple scenarios of restored floodplain based on adjustments of flood stage and topographic alterations. Ultimately, defining and quantifying the area inundated by the regular, frequent flood pulse supporting floodplain ecological processes will help managers plan and evaluate floodplain restoration projects.

Matern, S. A., and K.J. Fleming (1995). "Invasion of a third Asian goby Tridentiger bifasciatus in California." California Fish and Game 81: 71-76.

Matern, S. A. (2000). The Invasion of the Shimofuri Goby (Tridentiger bifasciatus) into California: Establishment, Potential for Spread, and Likely Effects. Davis, CA, University of California.

The San Francisco Bay/Delta estuary is dominated by nonindigenous species at nearly every taxonomic level. One of the most recent fish invaders is the shimofuri goby (Tridentiger bifasciatus), native to Asian estuaries. To predict the success and impact of the goby's continuing invasion, I examined its physiology, feeding ecology, and behavioral interactions with potential competitors. Shimofuri gobies have higher temperature tolerances than most fishes in the estuary (critical thermal maximum = 37 degree C when acclimated to 20 degree C). Although they cannot survive in undiluted seawater, shimofuri gobies tolerate wide fluctuations in salinity and can reproduce in fresh water. Thus, while they are capable of inland range expansion, a marine route of expansion is not possible. Shimofuri gobies are non-selective predators on benthic invertebrates, mainly amphipods, hydroids, and barnacle cirri. Hydroids are rare, and barnacle cirri are absent from the stomachs of other resident fishes. The goby's ability to specialize on seasonally abundant prey and to exploit two novel food sources makes it well-suited to the estuary and partially explains its impressive success relative to many resident species. In behavioral experiments with three ecologically similar resident fishes, shimofuri gobies were rarely submissive. Prickly sculpins (Cottus asper) and yellowfin gobies (Acanthogobius flavimanus) were rarely aggressive toward shimofuri gobies despite considerable size advantages. Sculpins and tidewater gobies (Eucyclogobius newberryi) were more submissive toward shimofuri gobies than toward conspecifics. Shimofuri gobies were more aggressive toward other gobies than toward sculpins. The invasion of the shimofuri goby is unlikely to be curbed by behavioral interactions with these species. However, if the shimofuri goby becomes sympatric with the endangered tidewater goby, populations of tidewater gobies may be eliminated through competition or predation. In laboratory experiments shimofuri gobies outcompeted a resident nonindigenous crab (Rhithropanopeus harrisii) for shelters. This was most pronounced during the day, when predators are active, and during the spawning season, when shelters are in short supply. The goby's invasion is unlikely to be affected by shelter competition with the crab, but the crab may suffer increased predation due to competitive exclusion from shelters.

Matern, S. A. (2001). "Using Temperature and Salinity Tolerances to Predict the Success of the Shimofuri Goby, a Recent Invader into California." Transactions of the American Fisheries Society 130(4): 592-599.

Shimofuri gobies Tridentiger bifasciatus recently invaded the San Francisco Estuary of California and appear to be physiologically well suited to the region. To assess the range expansion capability of the shimofuri goby, I used standard techniques to measure the critical thermal maxima (CTMax) at eight combinations of temperature (10 degree C and 20 degree C) and salinity (0, 5, 10, and 20) and I measured chronic upper salinity tolerance (CUST) at 20 degree C. Shimofuri goby CTMax was 37 degree C when acclimated to 20 degree C and was 3134 degree C when acclimated to 10 degree C. These values surpass those of most other resident fishes and allow the gobies to survive in small isolated pools at low tide, where temperatures change quickly and often exceed 30 degree C. Shimofuri goby CUST was 17, typical for estuarine fishes, but insufficient to allow for range expansion through seawater. Shimofuri gobies have been transported via the California State Water Project into freshwater reservoirs, where they appear to have established reproducing populations. From these populations, they may disperse downstream into southern Californian estuaries, possibly threatening the federally endangered tidewater goby Eucyclogobius newberryi.

Matern, S. A. and L. R. Brown (2005). "Invaders eating invaders: exploitation of novel alien prey by the alien shimofuri goby in the San Francisco Estuary, California." Biological Invasions 7(3): 497-507.

The shimofuri goby (Tridentiger bifasciatus), which is native to Asian estuaries, was recently introduced to the San Francisco Estuary, California, USA. We conducted gut content analyses to examine the goby's feeding ecology in this highly invaded estuary. Shimofuri gobies were generalist predators on benthic invertebrates, consuming seasonally abundant prey, especially amphipods (Corophium spp.). In addition, shimofuri goby utilized two novel prey items not exploited by other resident fishes - hydroids (Cordylophora caspia) and barnacle (Balanus improvisus) cirri, both of which are alien. The shimofuri goby's feeding ecology appears well-suited to the fluctuating environment of the San Francisco Estuary and may partially explain observed increases in shimofuri goby abundance compared with declines in populations of some native species.

Matern, S. A. and K. Fleming (1995). "Invasion of a third Asian goby, Tridentiger bifasciatus, in California." California Fish and Game 81: 71-76.

The Sacramento-San Joaquin Estuary is a major international port and ballast water dumping by ships has been the source of numerous introductions of exotic invertebrates and several fishes including the yellowfin goby, Acanthogobius flavimanus, and the chameleon goby, Tridentiger trigonocephalus. This note documents the establishment of a third exotic goby, Tridentiger bifasciatus.

Matern, S. A., P. B. Moyle, et al. (2002). "Native and alien fishes in a California estuarine marsh: Twenty-one years of changing assemblages." Transactions of the American Fisheries Society 131(5): 797-816.

We used monthly otter trawling and beach seining to sample the fishes of Suisun Marsh in the San Francisco Estuary from 1979 to 1999. We collected nearly 173,000 fish, mostly young of the year, representing 28 native species and 25 alien species. Catch data were related to temperature, salinity, water transparency, and several measures of freshwater inflow into the marsh. Species abundance and distribution within the marsh were the product of several interacting factors: (1) the timing and place of reproduction of the abundant resident species, (2) past reproductive success, (3) habitat differences among sloughs, and (4) physiological tolerance. We did not find consistent groups of potentially interacting species, although some native species showed weak concordance in abundance. The lack of persistent fish assemblages is related to the naturally fluctuating environmental conditions of the estuary, the overall decline in fish abundance through time, and the frequent invasions of alien fishes and invertebrates. Our results suggest that the fish assemblages in Suisun Marsh will continue to be unpredictable until estuarine processes approach their historic range of variability and alien invasions are halted.

Matiasek, S., B.A. Pellerin, P. Bachand, R. Spencer, B.A. Bergamaschi, and P.J. Hernes (2010). Partitioning of sediment-associated organic matter in the agricultural Willow Slough watershed: quantitative and qualitative characterization. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Sediment-associated organic matter (OM) may constitute a significant source of dissolved organic matter (DOM) in agricultural watersheds, but the partitioning of sediment-bound OM is still poorly characterized in such systems. In the agricultural Willow Slough watershed in Central Valley, California, weekly dissolved organic carbon (DOC) concentrations, collected at the watershed outlet in 2006 - 2008, increase during summer irrigation up to 7 mg/L, then return to winter baseline concentrations (2 mg/L). A similar trend is observed for total suspended sediment concentrations (TSS), which peak around 200 mg/L about five weeks earlier than DOC, suggesting that sediments may contribute significantly to the delivery of DOM. We

investigated the potential impact of sediment-bound OM partitioning on DOM concentration and composition from suspended, bed, and bank sediments and from cultivated soils, collected in the Willow Slough watershed over a range of land uses and hydrologic conditions. Desorption isotherms show distinct DOC contributions between sediment types; suspended sediment from summer irrigation exhibiting the highest initial OC content (1.6%) and largest partitioning potential (12%), while bed and bank sediment, along with soils, displayed a much lower OC desorption range (3-7%). In addition, environmental parameters such as water temperature, conductivity, and pH were found to affect OM partitioning differently, pH controlling DOC release the most (up to 64% DOC increase from pH 6.5 to pH 9.5). Finally, optical and biogeochemical characterization of the desorbed DOM (absorbance, fluorescence, and amino acids) provided insights on its composition, which was compared to riverine DOM quality. In particular, fluorescence index values indicated that chromophoric DOM derived from summer suspended sediment (1.8) was of more predominantly microbial origin than the chromophoric DOM desorbed from other sediment and soils (1.5-1.7). By assessing the contribution of DOM from sediments in agricultural watersheds, this research provides a better understanding of DOM origin and dynamics at the interface between soil and water ecosystems.

Matica, Z. and M. Nobriga (2005). "Modifications to an agricultural water diversion to permit fish entrainment sampling." California Fish and Game 91(1): 53-56.

May, C. L., J.R. Koseff, L.V. Lucas, J.E. Cloern, and D.H. Schoellhamer (2003). "Effects of spatial and temporal variability of turbidity on phytoplankton blooms." Marine Ecology Progress Series 254: 18.

A central challenge of coastal ecology is sorting out the interacting spatial and temporal components of environmental variability that combine to drive changes in phytoplankton biomass. For 2 decades, we have combined sustained observation and experimentation in South San Francisco Bay (SSFB) with numerical modeling analyses to search for general principles that define phytoplankton population responses to physical dynamics characteristic of shallow, nutrient-rich coastal waters having complex bathymetry and influenced by tides, wind and river flow. This study is the latest contribution where we investigate light-limited phytoplankton growth using a numerical model, by modeling turbidity as a function of suspended sediment concentrations (SSC). The goal was to explore the sensitivity of estuarine phytoplankton dynamics to spatial and temporal variations in turbidity, and to synthesize outcomes of simulation experiments into a new conceptual framework for defining the combinations of physical-biological forcings that promote or preclude development of phytoplankton blooms in coastal ecosystems. The 3 main conclusions of this study are: (1) The timing of the wind with semidiurnal tides and the spring-neap cycle can significantly enhance spring-neap variability in turbidity and phytoplankton biomass; (2) Fetch is a significant factor potentially affecting phytoplankton dynamics by enhancing and/or creating spatial variability in turbidity; and (3) It is possible to parameterize the combined effect of the processes influencing turbidity-and thus affecting potential phytoplankton bloom development-with 2 indices for vertical and horizontal clearing of the water column. Our conceptual framework is built around these 2 indices, providing a means to determine under what conditions a phytoplankton bloom can occur, and whether a potential bloom is only locally supported or system-wide in scale. This conceptual framework provides a tool for exploring the inherent light climate attributes of shallow estuarine ecosystems and helps determine susceptibility to the harmful effects of nutrient enrichment.

May, J. T. and L. R. Brown (2002). "Fish Communities of the Sacramento River Basin: implications for conservation of native fishes in the Central Valley, California." Environmental biology of fishes 63(4): 373-388.

The associations of resident fish communities with environmental variables and stream condition were evaluated at representative sites within the Sacramento River Basin, California between 1996 and 1998 using multivariate ordination techniques and by calculating six fish community metrics. In addition, the results of the current study were compared with recent studies in the San Joaquin River drainage to provide a wider perspective of the condition of resident fish communities in the Central Valley of California as a whole. Within the Sacramento drainage, species distributions were correlated with elevational and substrate size gradients; however, the elevation of a sampling site was correlated with a suite of water-quality and habitat variables that are indicative of land use effects on physio-chemical stream parameters. Four fish community metrics - percentage of native fish, percentage of intolerant fish, number of tolerant species, and percentage of fish with external anomalies - were responsive to environmental quality. Comparisons between the current study and recent studies in the San Joaquin River drainage suggested that differences in water-management practices may have significant effects on native species fish community structure. Additionally, the results of the current study suggest that index of biotic integrity-type indices can be developed for the Sacramento River Basin and possibly the entire Central Valley, California. The protection of native fish communities in the Central Valley and other arid environments continues to be a conflict between human needs for water resources and the requirements of aquatic ecosystems; preservation of these ecosystems will require innovative management strategies.

Mayr, S., S. Flory, B. Sunderland, and A. Smith (2010). Advancements in bathymetric data collection, storage, and dissemination. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Good bathymetry is the foundation for understanding almost any biological or physical process in the Sacramento-San Joaquin Delta. Unfortunately most of the historical data is spotty, out of date, and of variable quality. Because of recent key advancements, the time is right for coordinated actions to address all aspects of bathymetric information flow. These include: field collection methods, archiving, change analysis, data sharing, and dissemination. The ultimate goal is to produce an accurate, publicly available, continuously updated, Delta-wide dataset that is broadly available for a variety of scientific pursuits. This poster details advancements made by the North Central Region Office of the Department of Water Resources and others to help forward this goal.

McCreary, S., R. Twiss, et al. (1992). "Land use change and impacts on the San Francisco estuary." Coastal Management 20(3): 219-253.
The nation's estuaries are at risk of further deterioration from land use change and intensification. These risks include direct impacts on wetland habitats and stream environments and indirect impacts from nonpoint source pollutant loading. This article reports on the methods, findings, and policy implications of a major study, "The Effects of Land Use Change and Intensification on the San Francisco Estuary." By using a geographic information system (GIS), future growth scenarios were played out and the impacts on wetlands, streams, and water quality were estimated on a regionwide basis. The existing system of land use planning delegates responsibility to local governments. However, of 111 jurisdictions within the estuary study region, only 18 have specific ordinances to protect streams and wetlands. The results of the study suggest that improvements are needed in the goals, management strategies, and institutional arrangements now in place for the San Francisco estuary. The study recommends that a specific focus on estuarine resource protection be incorporated in any new growth management legislation enacted in California.

McCulloch, D. S., D. H. Peterson, et al. (1970). Some effects of freshwater inflow on the flushing of south San Francisco Bay: a preliminary report, US Geological Survey Circular 637-A.

McDonald, E. T. and R. T. Cheng (1994). Issues related to modeling the transport of suspended sediments in northern San Francisco Bay, California. Proceedings of the Third International Conference on Estuarine and Coastal Modeling. M. L. Spaulding, K. Bedford, A. Blumberg, R. Cheng and C. Swanson. Chicago, ASCE: 551-564.

McDonald, E. T. and R. T. Cheng (1997). "A numerical model of sediment transport applied to San Francisco Bay, California." Journal of Marine Environmental Engineering 4(1): 1-41.
A two dimensional depth-averaged sediment transport model is used to simulate field measurements of suspended sediment concentrations in northern San

Francisco Bay. The model uses a semi-implicit finite difference method to solve the shallow water equations and incorporates standard empirical expressions for erosion and deposition of sediments into the transport equation as source/sink terms. The field measurements indicate that tidal scale variations (both diurnal and spring-neap) dominate the variations in suspended sediment concentration (SSC). Increases in SSC also correlated highly with large delta outflows following a storm in late winter. The sediment transport model reproduces the field measurements quite well during periods when the water column is relatively well-mixed vertically. However, the present model only includes one size class of sediment and does not perform well when spatial variability of sediment properties and multiple size classes are significant factors. Comparison of erosion and accretion patterns generated by the model with those obtained from historical bathymetric surveys indicate that the model captures several of the general features observed historically. A sensitivity analysis demonstrates that the model is very sensitive to the critical shear stress for erosion and moderately sensitive to the erosion rate constant, critical shear stress for deposition, and settling velocity.

McEwan, D. R., and J. Nelson (1991). Steelhead restoration plan for the American River, California Department of Fish and Game: 40 pp.

McEwan, D. R., and T.A. Jackson (1996). Steelhead restoration and management plan for California, California Department of Fish and Game: 246 pp.
This plan focuses on restoration of native and naturally produced (wild) stocks because these stocks have the greatest value for maintaining genetic and biological diversity. Goals for steelhead restoration and management are 1) increase natural production, as mandated by The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988, so that steelhead populations are self-sustaining and maintained in good condition and 2) enhance angling opportunities and non-consumptive uses. Strategies to accomplish these goals are 1) restore degraded habitat 2) restore access to historic habitat that is presently blocked 3) review angling regulations to ensure that steelhead adults and juveniles are not over-harvested 4) maintain and improve hatchery runs, where appropriate and 5) develop and facilitate research to address deficiencies in information on fresh water and ocean life history, behavior, habitat requirements, and other aspects of steelhead biology.

McEwan, D. R. (2001). Central Valley steelhead. Contributions to the biology of the Central Valley salmonids: Fish Bulletin 179. R.L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 1: 1-44.
Before extensive habitat modification of the 19th and 20th centuries, steelhead (Oncorhynchus mykiss) were broadly distributed throughout the Sacramento and San Joaquin drainages. Historical run size is difficult to estimate given the paucity of data, but may have approached 1 to 2 million adults annually. By the early 1960s run size had declined to about 40,000 adults. Natural spawning populations currently exist in the Sacramento and San Joaquin river systems but at much lower levels. Coastal rainbow trout populations can be polymorphic in their life-history, and progeny of one life-history form can assume a life-history strategy different from that of their parents. A polymorphic population structure may be necessary for the longterm persistence in highly variable environments such as the Central Valley. Despite the substantial introduction of exotic stocks for hatchery production, native Central Valley steelhead may have maintained some degree of genetic integrity. Primary stressors affecting Central Valley steelhead are all related to water development and water management, and the single greatest stressor is the substantial loss of spawning and rearing habitat due to dam construction. Central Valley anadromous fish management and research is primarily focused on chinook salmon (Oncorhynchus tshawytscha) and has lead to less emphasis on steelhead monitoring and restoration. Much of the information on historical abundance and stock characteristics that exists for Central Valley steelhead is derived from an intensive DFG research program in the 1950s. Since this time there has been relatively little research directed at steelhead in the Central Valley, and efforts to restore Central Valley steelhead have been greatly hampered by lack of information. The National Marine Fisheries Service cited the ongoing conservation efforts of the Central Valley Project Improvement Act (CVPIA) and CALFED as

justification for listing Central Valley steelhead as a threatened species under the Endangered Species Act, rather than endangered as proposed. Restoration actions identified in these programs are largely directed at chinook salmon recovery with comparatively little emphasis on specific actions needed to recover steelhead, or have not yet been implemented. The structure of rainbow trout populations has important management implications that can only be addressed through an integrated management strategy that treats all life-history forms occupying a stream as a single population. However, management agencies have generally failed to recognize this, as exemplified by the federal government’s decision to exclude the non-anadromous forms in the ESA listing for steelhead, despite their recognition that they are important to the persistence of the anadromous forms. Steelhead need to be managed separately from chinook salmon stocks if recovery is to be successful, and recovery strategies must include measures to protect and restore the ecological linkages between the different life-history forms and measures to restore steelhead to some of their former habitat.

McGourty, C., J. Hobbs, et al. (2009). "Likely Population-Level Effects of Contaminants on a Resident Estuarine Fish Species: Comparing Gillichthys mirabilis Population Static Measurements and Vital Rates in San Francisco and Tomales Bays." Estuaries and Coasts 32(6): 1111-1120.

Abstract   Gillichthys mirabilis population static measurements (abundance, age, and size class structures) and vital rates (growth, mortality, recruitment) were monitored on an annual basis from 2002 to 2007. Population-level metrics were used to gauge habitat quality at two study sites (a contaminated site and a reference site) in two large northern California estuaries (San Francisco and Tomales Bays). San Francisco Bay populations exhibited slower growth and higher mortality rates and contained higher amounts of contaminants than Tomales Bay. Recruitment rates were highest at contaminated sites (Stege Marsh and Walker Creek) in 3 years out of 5 years, suggesting low adult survival. This study suggests that population-level effects on a residential fish may be attributed to estuarine contamination on the US Pacific coast.

McGowan, M. F. (1986). "Northern anchovy, Engraulis mordax, spawning in San Francisco Bay, California, 1978-79, relative to hydrography and zooplankton prey of adults and larvae." Fisheries Bulletin 84: 879-894.

Eggs and larvae of Engraulis mordax were sampled by nets monthly for one year. Either eggs or larvae were caught every month. Both were most abundant when water temperature was high. Mean egg abundance did not differ among stations but larvae were more abundant within the San Francisco Bay at high and low salinity than near the ocean entrance to the Bay. Larvae longer than 15 mm were collected over the shoals in spring and autumn but were in the channel during winter. Zooplankton and microzooplankton were abundant relative to mean California Current densities. Adult spawning biomass in the Bay was 767 tons in July 1978, based on egg abundance and fecundity parameters of oceanic animals. San Francisco Bay was a good spawning area for northern anchovy because food for adults and larvae was abundant and because advective losses of larvae would have been lower in the Bay than in coastal waters at the same latitude.

McKechnie, R. J. and L. W. Miller (1971). "The striped bass party boat fishery: 1960-1968." California Fish and Game 57: 4-16.

McKee, L., and M. Lewicki (2010). New estimates of suspended sediment loads to San Francisco Bay. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Information on suspended sediment loads is of paramount importance for managing the Bay-Delta due to associated degradation of water and sediment quality, recreation amenities, native species habitat, and disruption of commercial shipping operations. Yet we still have limited understanding of suspended sediment and contaminant loads in various components of the ecosystem. Research in the 1970s and 80s provided evidence that approximately 80% of the sediment supply to the Bay was from the Central Valley. Since then, sediment loads from the Central Valley have trended downwards, a premise promulgated by Krone (1996) in Hollibaugh (Ed.) San Francisco Bay: The Ecosystem and confirmed by Wright and Schoellhamer (2004). Based on point and cross section measurements of turbidity and suspended sediment concentrations at Mallard Island, we presented evidence that the average annual suspended sediment load passing from the Central Valley through the Delta past Mallard Island is now 1 million metric t (McKee et al. 2006: Journal of Hydrology). Recently we completed a new evaluation of suspended sediment loads in small tributaries of the nine county Bay Area using a combination of 177 station years of sediment data covering 29 watersheds, regression analysis, and simple modeling (Lewicki and McKee, 2009: SFEI technical report). Along with updated estimates of Delta loads, this research shows that an estimated 1.3 million metric t is supplied from the tributaries of the nine-county Bay Area, and that the balance is tipped even more than Krone had predicted. Our results imply that the Bay suspended sediment budget is now dominated by supply of fine more highly contaminated sediment from urbanized nine-county Bay Area tributaries. Managers responsible for sediment accumulating in shipping channels and restoring wetlands may need to more carefully account for proximity to urban tributaries and contaminant sources.

McKee, L. J., N. K. Ganju, et al. (2006). "Estimates of suspended sediment entering San Francisco Bay from the Sacramento and San Joaquin Delta, San Francisco Bay, California." Journal of Hydrology 323(1-4): 335-352.

This study demonstrates the use of suspended-sediment concentration (SSC) data collected at Mallard Island as a means of determining suspended-sediment load entering San Francisco Bay from the Sacramento and San Joaquin River watersheds. Optical backscatter (OBS) data were collected every 15 min during water years (WYs) 1995-2003 and converted to SSC. Daily fluvial advective sediment load was estimated by combining estimated Delta outflow with daily averaged SSC. On days when no data were available, SSC was estimated using linear interpolation. A model was developed to estimate the landward dispersive load using velocity and SSC data collected during WYs 1994 and 1996. The advective and dispersive loads were summed to estimate the total load. Annual suspended-sediment load at Mallard Island averaged 1.2 +/- 0.4 Mt (million metric tonnes). Given that the average water discharge for the 1995-2003 period was greater than the long-term average discharge, it seems likely that the average suspended-sediment load may be less than 1.2 0.4 Mt. Average landward dispersive load was 0.24 Mt/yr, 20% of the total. On average during the wet season, 88% of the annual suspended-sediment load was discharged through the Delta and 43% occurred during the wettest 30-day period. The January 1997 flood transported 1.2 Mt of suspended sediment or about 11% of the total 9-year load (10.9 Mt). Previous estimates of sediment load at Mallard Island are about a factor of 3 greater because they lacked data downstream from riverine gages and sediment load has decreased. Decreasing suspended-sediment loads may increase erosion in the Bay, help to cause remobilization of buried contaminants, and reduce the supply of sediment for restoration projects. (c) 2005 Elsevier B.V. All rights reserved.

McLain, J. and G. Castillo (2009). "Nearshore areas used by fry Chinook salmon, Oncorhynchus tshawytscha, in the northwestern Sacramento-San Joaquin Delta, California." San Francisco Estuary and Watershed Science 7(2).

McLaughlin, K., C. Kendall, et al. (2006). "Phosphate oxygen isotope ratios as a tracer for sources and cycling of phosphate in North San Francisco Bay, California." Journal of Geophysical Research-Biogeosciences 111(G3).

[1] A seasonal analysis assesing variations in the oxygen isotopic composition of dissolved inorganic phosphate (DIP) was conducted in the San Francisco Bay estuarine system, California. Isotopic fractionation of oxygen in DIP (exchange of oxygen between phosphate and environmental water) at surface water temperatures occurs only as a result of enzyme-mediated, biological reactions. Accordingly, if phospate demand is low relative to input and phosphate is not heavily cycled in the ecosystem, the oxygen isotopic composition of DIP (delta O-18(p)) will reflect the isotopic composition of the source of phosphate to the system. Such is the case for the North San Francisco Bay, an anthropogenically impacted estuary with high surface water phosphate concentrations. Variability in the delta O-18(p) in the bay is primarily controlled by mixing of water masses with different delta O-18(p) signatures. The delta O-18(p) values range from 11.4 parts per thousand at the Sacramento River to 20.1 parts per thousand at the Golden Gate. Deviations from the two-component mixing model for the North Bay reflect additional,

local sources of phosphate to the estuary that vary seasonally. Most notably, deviations from the mixing model occur at the confluence of a major river into the bay during periods of high river discharge and near wastewater treatment outlets. These data suggest that delta O-18(p) can be an effective tool for identifying P point sources and understanding phosphate dynamics in estuarine systems.

McLeod, P. B., M. J. Van den Heuvel-Greve, et al. (2007). "Biological Uptake of Polychlorinated Biphenyls By Macoma Balthica from Sediment Amended with Activated Carbon." Environmental Toxicology and Chemistry 26(5): 980-987.

This work characterizes the efficacy of activated carbon amendment in reducing polychlorinated biphenyl (PCB) bioavailability to clams (Macoma balthica) from field-contaminated sediment (Hunters Point Naval Shipyard, San Francisco Bay, CA, USA). Test methods were developed for the use of clams to investigate the effects of sediment amendment on biological uptake. Sediment was mixed with activated carbon for one month. Bioaccumulation tests (28 d) were employed to assess the relationships between carbon dose and carbon particle size on observed reductions in clam biological uptake of PCBs. Extraction and cleanup protocols were developed for the clam tissue. Efficacy of activated carbon treatment was found to increase with both increasing carbon dose and decreasing carbon particle size. Average reductions in bioaccumulation of 22, 64, and 84% relative to untreated Hunters Point sediment were observed for carbon amendments of 0.34, 1.7, and 3.4%, respectively. Average bioaccumulation reductions of 41, 73, and 89% were observed for amendments (dose = 1.7% dry wt) with carbon particles of 180 to 250, 75 to 180, and 25 to 75 mu m, respectively, in diameter, indicating kinetic phenomena in these tests. Additionally, a biodynamic model quantifying clam PCB uptake from water and sediment as well as loss through elimination provided a good fit of experimental data. Model predictions suggest that the sediment ingestion route contributed 80 to 95% of the PCB burdens in the clams.

McManus, G. B., J. K. York, et al. (2008). "Microzooplankton dynamics in the low salinity zone of the San Francisco Estuary." Verh. Internat. Verein. Limnol. 30(2): 196-202.

McMillin, S., D. Waligora, and S. Blaser (2010). Effects of diuron on algal growth: Comparison of algal bioassay and grow-out experiments. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The Pelagic Organism Decline (POD) in the Sacramento-San Joaquin Delta has been well documented and several hypotheses given for its cause. The bottom-up hypothesis proposes that lack of availability of food may be causing the decline of fish populations. Some data do suggest that low primary production is a principal cause for the POD. Primary production may be reduced by the presence of pollutants, such as herbicides, in the watershed. The phenylurea herbicide diuron is one of the most heavily used pesticides in California, has moderate to high water solubility, is relatively toxic, and persists in the environment. It has been detected in a majority of samples collected for diuron analysis in the SF Estuary, yet little is known about consequences to the phytoplankton community. Algal bioassays and grow-out experiments were performed to determine effects of elevated diuron concentrations to phytoplankton. These two different approaches were performed on the same water samples collected from the Sacramento River at Rio Vista and the central San Francisco Bay that were spiked with a series of diuron concentrations up to 5 µg/L. Bioassays using green alga Selenastrum capricornutum and diatom Skeletonema costatum were performed to determine toxicity values for diuron. Water for these bioassays was filtered to remove existing plankton communities. Grow-out experiments were also performed on unfiltered water to assess the impact of diuron on primary production and community composition of natural phytoplankton communities. This approach of using natural mixed phytoplankton communities allows the examination of effects to both productivity and phytoplankton diversity. Traditional algal test showed a significant negative effect only at the highest concentration of 5µg/L. Alternatively, the results from the natural phytoplankton grow-out experiment showed a significant decline in productivity at a lower diuron concentration of approximately 1µg/L. Differences between the two approaches may be due to higher sensitivity of some species in the mixed community. These results

highlight that diuron may be negatively effecting the phytoplankton community in the San Francisco Estuary which may in turn be effecting higher trophic levels and contributing to the POD.

McNabb, C. D., C. R. Liston, et al. (2003). "Passage of Juvenile Chinook Salmon and Other Fish Species through Archimedes Lifts and a Hidrostal Pump at Red Bluff, California." Transactions of the American Fisheries Society 132(2): 326-334.
Fish were passed through two large Archimedes lifts and a large Hidrostal pump at the U.S. Bureau of Reclamation's experimental pumping plant on the upper Sacramento River, California. Two of the pumps were run concurrently during trials to compare their effects on hatchery-reared juvenile chinook salmon Oncorhynchus tshawytscha. In each trial, control samples were released at pump outfalls, and treatment samples were inserted into the intake of each pump. Fish in samples were collected in downstream holding tanks. In 27 trials comparing the two Archimedes lifts, mean survival for paired control and treatment groups was 98.3-99.0% for both lifts. Effects from pump passage were not detected for either lift at alpha = 0.05. In 40 trials comparing the Archimedes lifts and Hidrostal pump, mean survival for paired control and treatment groups was 96.5- 99.5% for both pump types. Effects of passage through these small pumps were detected: 0.9% for the Archimedes lifts and 2.4% for the Hidrostal pump. To examine their effects on riverine fish, the two Archimedes lifts and the Hidrostal pump were run concurrently for 24 h during 24 trials. The pumps entrained 3,337 juvenile chinook salmon and 2,773 fish of 27 other species. Survival per pump for riverine chinook salmon and the other species taken collectively ranged from 94% to 98%, and among-pump differences were not statistically significant. Postpassage examinations of chinook salmon from experimental trials and entrained riverine fish revealed a very low incidence of potentially debilitating injuries among surviving individuals. Because of these results and supporting data in other studies, this pumping technology is being considered for use at other water diversion sites in California to protect fisheries resources.

Meckstroth, A. M. and A. K. Miles (2005). "Predator Removal and Nesting Waterbird Success at San Francisco Bay, California." Waterbirds 28(2): 250-255.
The efficacy of long-term predator removal in urbanized areas is poorly understood. The impact of predation on ground-nesting waterbirds, as well as predator abundance and composition in predator removal versus non-removal or reference sites were examined at South San Francisco Bay. The success of natural nests and predator activity was monitored using track plates, trip cameras, wire haircatchers and simulated nests. Removal sites had higher nest densities, but lower hatching success than reference sites. Predator composition and abundance were not different at the removal and reference sites for any predator other than feral Cat (Felis domesticus). Striped Skunk (Mephitis mephitis) comprised the majority (84%) of predators removed, yet remained the most abundant predators in removal and reference sites. Urban environments provide supplemental food that may influence skunks and other nest predators to immigrate into vacancies created by predator removal. Based on the findings from this study, predator removal should be applied intensively over a larger geographic area in order to be a viable management strategy for some mammalian species in urbanized areas.

Medellin-Azuara, J., R. Howitt, D. MacEwan, and J.R. Lund (2010). Improved agricultural water use modeling in California using remote sensing. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
We present hydro-economic modeling of California agriculture employing a self-calibrated optimization model and remote sensing information. The Statewide Agricultural Production Model (SWAP,http://swap.ucdavis.edu) in California’s Central Valley calibrates agricultural production to observed values of input use. Remote for fallowing, evapotranspiration, and biomass among other variables from SEBAL (http://www.sebal.us/) seasonal satellite imagery post-processing is employed to validate water balance and land use information. Preliminary results contrast SWAP predicted land fallowing and SEBAL actual land fallowing resulting from reductions in contract water deliveries in recent years. The prospects for using such remote sensing data for water management and policy information are also

discussed.

Meek, D. W., J. L. Hatfield, et al. (1984). "A generalized relationship between photosynthetically active radiation and solar radiation." Agronomy Journal 76(6): 939-945.
Photosynthetically active radiation (PAR) is a necessary input in several crop growth models. Previous research from several locations with different instruments has suggested that PAR could be estimated as a constant fraction of shortwave radiation. This study was conducted to determine if a simple relationship was valid for a large geographic area in the western half of the USA. In the semiarid climate near Fresno, CA, the daily photosynthetic photon flux density (PPFD) in units of µmol m–2 was 2.04 ± 0.06 times the solar irradiance (SI). The daily irradiance within the PAR waveband (photosynthetic irradiance (PI), 0.4 to 0.7 µm) was estimated to be 45% of the daily solar irradiance. The diurnal pattern of these relationships was consistent with measurements at Phoenix, AZ and exhibited only a slight diurnal variation. Independent measurements of the solar irradiance between 0.285 and 0.63 µm with "filtered" pyranometers at the Fresno site indicated that irradiance between 0.285 and 0.63 pm was 41% of solar irradiance, a result which was about 7% lower than the estimate from the PAR/SI value converted with a published sun and sky PAR/PI factor. This difference was largely attributed to the differences in measured wavebands. Measurements of solar irradiance less than the waveband of 0.63 µm and total solar irradiance obtained with the same equipment at Brawley, CA; Weslaco, TX; Temple, TX; Manhattan, KS; Lincoln, NE; St. Paul, MN; Fargo, ND; Sidney, MT; Beartooth Pass, WY; Kimberly, ID; Davis, CA were similar to those measured at Fresno, CA. The results indicate that PAR can be estimated from solar irradiance measurements to within 10% (which is probably acceptable for most plant growth models) throughout most of the Western USA.

Meek, M., A. Wintzer, N. Elen, and B. May (2010). Sex, clones, and Suisun Marsh: Genetic diversity and reproductive mode in two species of invasive hydromedusae in the upper San Francisco Estuary. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Three species of non-native hydromedusae have become established in the brackish water habitats of the San Francisco Estuary (Maeotias marginata, Blackfordia virginica, Moerisia sp.). Their impact on the aquatic community maybe great, as they are novel predators in this system with high density seasonal blooms. Despite their likely ecological importance, relatively little is understood about the ecologies of these non-natives, their impacts, and what makes them so successful outside their native range. Included in this paucity of understanding is knowledge of the overall genetic diversity of the population and the relative contribution of asexual and sexual reproduction to its growth. In this study, we examine these unknowns in M. marginata and the Moerisia species. We developed microsatellite genetic markers to investigate the clonal diversity of these species collected from Suisun Marsh in the upper San Francisco Estuary. We quantified overall genetic diversity and examined clonal diversity. Our results show relatively high genetic diversity, as would be expected with sexual reproduction, but also a strong presence of asexual reproduction. Our findings demonstrate the importance of these modes of reproduction to the invasion and provide insights into characteristics that may make them successful invaders in the Bay-Delta system.

Meinz, M., and W.L. Mecum (1977). "A range extension of Mississippi silversides in California." California Fish and Game 63: 277-278.

Mejia, F., M.K. Saiki, and J. Y. Takekawa (2008). "Relation Between Species Assemblages Of Fishes and Water Quality In Salt Ponds and Sloughs In South San Francisco Bay." Southwestern Naturalist 53 (3): 335-345.
This study was conducted to characterize fishery resources inhabiting salt-evaporation ponds and sloughs in South San Francisco Bay, and to identify key environmental variables that influence distribution of fishes. The ponds, which were originally constructed and operated for commercial production of salt, have undergone preliminary modifications (installation of culverts, gates, and other water-control structures) in preparation for full restoration to mostly tidal wetlands over the next 2 decades. We sampled fish from two salt-pond complexes

(Alviso complex and Eden Landing complex), each consisting of several pond systems and their associated sloughs. Cluster analysis of species of fish indicated that at least two species assemblages were present, one characteristic of ponds and the other characteristic of sloughs and slough-like ponds. The slough-like ponds exhibited water-quality conditions (especially salinity) that resembled conditions found in the sloughs. Pond fishes were represented by 12 species, whereas slough fishes were represented by 22 species. Except for bay pipefish (Syngnathus leptorhynchus), which was unique to ponds, all species present in ponds also were in sloughs and slough-like ponds. These results indicated that species of fish in ponds originated from the sloughs. According to canonical-discriminant analysis, four environmental variables were useful for discriminating between the two species assemblages. Most discriminatory power was contributed by the index of habitat connectivity, a measure of minimum distance that a fish must travel to reach a particular pond from the nearest slough. Apparently, as fish from sloughs enter and move through interconnected salt ponds, environmental stress factors increase in severity until only the more tolerant species remain. The most likely source of stress is salinity, because this variable was second in importance to the index of habitat connectivity in discriminating between the two species assemblages. Water temperature and concentration of dissolved oxygen also seemingly influenced spatial distribution of fishes, although they were less important than salinity.

Mejia, F., and M. Dempsey (2010). Delta smelt spawning and turbidity patterns. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Previous studies have suggested that delta smelt (Hypomesus transpacificus) population has declined dramatically in recent years due to the reduction of suitable habitat. This reduction of habitat has been attributed to a number of abiotic factors such as turbidity as well as biotic factors such as low food supply. A number of studies have documented that turbidity is a major factor affecting the quality of delta smelt fall and summer habitat as well as their upstream migration (Feyrer et al. 2007, Nobriga et al 2008, and Grimaldo et al. 2009). Hence, there is a need to have a better understanding of habitat variability for this species. This study is primarily descriptive with two objectives that hope to address 1) how turbidity varies across regions of San Francisco estuary, and 2) how this variability corresponds to delta smelt habitat during their spawning period. Delta smelt catch data from the Department of Fish and Game spring kodiak trawl survey were compared against horizontal turbidity profiles collected by the Department of Water Resources for 2010. Delta smelt distribution followed similar high turbidity distribution. Continuous water quality horizontal profiles were used to provide a snapshot in time on not only delta smelt habitat variability but also habitat connectivity and give us a further understanding on the habitat conditions that delta smelt encounter across their range during spawning.

Mejia, F., S. Waller, M. Dempsey, and E. Haydt (2010). Turbidity patterns in the San Francisco Estuary along a longitudinal transect. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Mekebri, A., D. Crane, and K. Regalado (2010). Recent advances in the analysis of pyrethroid insecticides in surface water and sediments. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Recent advances in analytical instrumentation have allowed the development of new analysis methods for pyrethroid insecticides in surface water and sediments. The analytes include seven pyrethroid insecticides used in agriculture and structural pest control in California including bifenthrin, cyfluthrin, cypermethrin, esfenvalerate, fenvalerate, lambda-cyhalothrin, and permethrin. Fortified water samples were extracted by liquid-liquid extraction, sediment samples were extracted using pressurized fluid extraction. Sample extracts were analyzed using negative chemical ionization tandem mass spectrometry (NCI-MSMS) using ammonia ionization gas. Method detection limits have been established for water and sediment that are below the toxicity of the analytes.

Meko, D. M., M. D. Therrell, et al. (2001). "Sacramento river flow reconstructed to

A.D. 869 from tree rings." Journal of the American Water Resources Association 37(4): 1029-1040.
A time series of annual flow of the Sacramento River, California, is reconstructed to A.D. 869 from tree rings for a long-term perspective on hydrologic drought. Reconstructions derived by principal components regression of flow on time-varying subsets of tree-ring chronologies account for 64 to 81 percent of the flow variance in the 1906 to 1977 calibration period. A Monte Carlo analysis of reconstructed n-year running means indicates that the gaged record contains examples of drought extremes for averaging periods of perhaps = 6 to 10 years, but not for longer and shorter averaging periods. For example, the estimated probability approaches 1.0 that the flow in A.D. 1580 was lower than the lowest single-year gaged flow. The tree-ring record also suggests that persistently high or low flows over 50-year periods characterize some parts of the long-term flow history. The results should contribute to sensible water resources planning for the Sacramento Basin and to the methodology of incorporating tree-ring data in the assessment of the probability of hydrologic drought.

Meng, L., and J.J. Orsi. (1991). "Selective predation by larval striped bass on native and introduced copepods." Transactions of the American Fisheries Society 120: 187-192.
Year-class strength of striped bass Morone saxatilis is often determined by the success of first-feeding larvae. In the Sacramento-San Joaquin estuary, this success may be influenced by the recent invasion of exotic copepods that appear to be displacing native copepods important as food. We tested selection by larval striped bass on native copepods (Eurytemora affinis and Cyclops sp.) and on introduced copepods (Sinocalanus doerri and Pseudodiaptomus forbesi). Two-species and single-species tests established the following order of preference: Cyclops sp. (most preferred), E. affinis, P. forbesi, and S. doerri (rarely eaten). Tests to evaluate the underlying mechanism of prey selection showed that the presence of egg sacs and copepod size did not affect the larvae's choice of prey. Instead, selection by larval striped bass apparently involved differences in copepod swimming and escape behaviors.

Meng, L., P.B. Moyle, and B. Herbold. (1994). "Changes in abundance and distribution of native and introduced fishes of Suisun Marsh." Transactions of the American Fisheries Society 123: 498-507.
We sampled ichthyoplankton weekly in Suisun Marsh in the San Francisco Estuary from February to June each year from 1994 to 1999. We collected approximately 227,900 fish, predominantly shimofuri goby Tridentiger bifasciatus (60%) and prickly sculpin Cottus asper (33%). Principal components analysis and canonical correspondence analysis were used to explore relationships among several environmental variables and the 13 species that made up 99.96% of the catch. A group of native fishes (prickly sculpin, Sacramento sucker Catostomus occidentalis, threespine stickleback Gasterosteus aculeatus, longfin smelt Spirinchus thaleichthys, and Sacramento splittail [also known simply as splittail] Pogonichthys macrolepidotus) were associated with the cool temperatures and higher outflows characterizing early-season conditions in Suisun Marsh. In contrast, a group of introduced species (shimofuri goby, inland silverside Menidia beryllina, striped bass Morone saxatilis, and threadfin shad Dorosoma petenense) were associated with the warm temperatures and lower outflows that characterize late-season marsh conditions. Catch composition was similar among marsh waterways (called sloughs), except for Cordelia Slough in the western marsh, which had lower total catch, greater diversity, and most of the threespine stickleback, northern anchovy Engraulis mordax, and longfin smelt. Longfin smelt were captured mostly in February and March, whereas delta smelt Hypomesus transpacificus catches were later and more evenly distributed throughout the marsh. Delta smelt catches overlapped temporally and spatially with catches of the introduced wakasagi H. nipponensis. Sacramento splittail catches were confined mostly to 1995, a year when high flows peaked during their spawning season in March and April. Our results suggest that temperature and interannual variations in freshwater flow are important for determining habitat quality for native and introduced larval fishes. We conclude that mimicking natural flow regimes in this highly regulated system is important for early life stages of native fishes.

Meng, L., and P. B. Moyle. (1995). "Status of splittail in the Sacramento-San Joaquin Estuary." Transactions of the American Fisheries Society 124: 538-549.
Analysis of data from four extensive fish surveys in the Sacramento-San Joaquin estuary indicated that splittail Pogonichthys macrolepidotus, endemic to the Central Valley of California, declined by 62% over a 13-year period. Splittails are now found mostly in the estuary, a fraction of their former range. In a gill-net survey in August 1994, 50% of the splittails taken in the estuary were from the Suisun Bay area, and 50% were just upstream in shallow, well-vegetated areas. Splittails migrate into freshwater to spawn, and river outflow carries juveniles into productive, shallow, low-salinity areas downstream. The high correlation of abundance of young with river outflow (average r2, 0.60) and a weak stock-recruitment relationship (r2 = 0.22) indicate that spawning success depends on favorable environmental conditions created by high outflows, such as the number of days that lowland areas remain flooded in the spring. A repeated-measures analysis of variance indicated that splittails prefer shallow, low-salinity habitats. The reductions in splittail abundance and range and the movements and habitat preferences of splittail young and adults correspond to trends and habits of two other species characteristic of the estuary, delta smelt Hypomesus transpacificus and longfin smelt Spirinchus thaleichthys. The largest threats to these three species are changes in water management and increases in water diversions that reduce spawning and rearing areas and other low-salinity habitats in Suisun Bay.

Meng, L., and S.A. Matern. (2001). "Native and introduced larval fishes of Suisun Marsh, California: The effects of freshwater flow." Transactions of the American Fisheries Society 130(5): 750-765.
We sampled ichthyoplankton weekly in Suisun Marsh in the San Francisco Estuary from February to June each year from 1994 to 1999. We collected approximately 227,900 fish, predominantly shimofuri goby Tridentiger bifasciatus (60%) and prickly sculpin Cottus asper (33%). Principal components analysis and canonical correspondence analysis were used to explore relationships among several environmental variables and the 13 species that made up 99.96% of the catch. A group of native fishes (prickly sculpin, Sacramento sucker Catostomus occidentalis, threespine stickleback Gasterosteus aculeatus, longfin smelt Spirinchus thaleichthys, and Sacramento splittail [also known simply as splittail] Pogonichthys macrolepidotus) were associated with the cool temperatures and higher outflows characterizing early-season conditions in Suisun Marsh. In contrast, a group of introduced species (shimofuri goby, inland silverside Menidia beryllina, striped bass Morone saxatilis, and threadfin shad Dorosoma petenense) were associated with the warm temperatures and lower outflows that characterize late-season marsh conditions. Catch composition was similar among marsh waterways (called sloughs), except for Cordelia Slough in the western marsh, which had lower total catch, greater diversity, and most of the threespine stickleback, northern anchovy Engraulis mordax, and longfin smelt. Longfin smelt were captured mostly in February and March, whereas delta smelt Hypomesus transpacificus catches were later and more evenly distributed throughout the marsh. Delta smelt catches overlapped temporally and spatially with catches of the introduced wakasagi H. nipponensis. Sacramento splittail catches were confined mostly to 1995, a year when high flows peaked during their spawning season in March and April. Our results suggest that temperature and interannual variations in freshwater flow are important for determining habitat quality for native and introduced larval fishes. We conclude that mimicking natural flow regimes in this highly regulated system is important for early life stages of native fishes.

Merz, J. E., and C.D. Vanicek (1996). "Comparative feeding habits of juvenile chinook salmon, steelhead, and Sacramento squawfish in the lower American River, California." California Fish and Game 82(4): 149-159.
We compared diets of juvenile Chinook salmon, Oncorhynchus tshawytscha, steelhead, O. mykiss, and Sacramento squawfish, Ptychocheilus grandis, in the lower American River from February through July 1992 and 1993. Chinook salmon and steelhead fed primarily on chironomids (all stages), baetids (adults and nymphs), and hydropsychids (larvae and pupae); their diets overlapped significantly in May and June. Squawfish diet consisted mainly of corixid adults and chironomid larvae

and did not overlap significant with either Chinook salmon or steelhead diets. Food habitats changed somewhat as the season progressed and fish increased in size. In 1993, Chinook salmon and steelhead fed less than in the previous year and relied more on chironomids. We attribute these differences in diet to the major fluctuations in discharge and lower water temperatures that occurred in the lower American River that year.

Merz, J. E. (2002). "Comparison of diets of prickly sculpin and juvenile fall-run chinook salmon in the lower Mokelumne River, California." Southwestern Naturalist 47(2): 195-204.
I compared diets of prickly sculpin, Cottus asper, and juvenile fall-run chinook salmon, Oncorhynchus tshawytscha, in the lower Mokelumne River, California, from January through June during 1998 and 1999. Prickly sculpin fed primarily on chironomid (Diptera) larvae and hydroptilid and hydropsychid (Trichoptera) larvae. Juvenile chinook salmon fed on zooplankton, plus chironomid, hydroptilid, and hydropsychid pupae. Both supplemented their diets with several other prey items, including larval Sacramento suckers, Catostomus occidentalis. Their diets did not overlap significantly any time during the study. Each species fed more as time progressed in both years. A significant relationship between prey item and fish size was observed for juvenile chinook salmon in 1998 and for both species in 1999. The pattern of growth for chinook salmon and prickly sculpin suggests increased feeding might be more related to water temperature than increase in size. I observed no predation by prickly sculpin on juvenile chinook salmon during this study, although sculpin eggs and larvae were infrequently observed in salmon stomachs.

Merz, J. E. and P. B. Moyle (2006). "Salmon, wildlife, and wine: Marine-derived nutrients in human-dominated ecosystems of central California." Ecological Applications 16(3): 999-1009.
Pacific salmon transfer large quantities of-marine-derived nutrients to adjacent forest ecosystems with profound effects on plant and wildlife production. We investigated this process for two highly modified California wine country rivers, one with consistent salmon runs (Mokelumne River) and one without (Calaveras River). Mokelumne River Chinook salmon transported biomass and N comparable to Pacific Northwest salmon streams. Calaveras River levels were much less. Scavenger numbers correlated with salmon carcass counts over time on the Mokelumne River but not the Calaveras River. Likewise, salmon carcasses were consumed significantly faster on the Mokelumne River. Native riparian vegetation as well as cultivated wine grapes adjacent to Mokelumne River spawning sites received 18-25% of foliar N from marine sources, significantly higher than vegetation along the Calaveras River. These data suggest that robust salmon runs continue to provide important ecological services with high economic value, even in impaired watersheds. Loss of Pacific salmon can not only negatively affect stream and riparian ecosystem function, but can also affect local economies where agriculture and salmon streams coexist.

Merz, J. E., G. B. Pasternack, et al. (2006). "Sediment budget for salmonid spawning habitat rehabilitation in a regulated river." Geomorphology.
Bed elevation, feature adjustments, and spawning use were monitored at three Chinook salmon (Oncorhynchus tschawytscha)
spawning habitat rehabilitation sites to measure project longevity in a regulated river. Sites enhanced with 649–1323 m3 of gravel
lost from 3–20% of remaining gravel volume annually during controlled flows of 8–70 m3/s and 2.6–4.6% of placed material
during a short-duration (19 days) release of 57 m3/s. The oldest site lost ~50% of enhancement volume over 4 years. Of the
mechanisms monitored, gravel deflation was the greatest contributor to volumetric reductions, followed by hydraulic scour.
Spawning, local scour around placed features, and oversteepened slopes contributed to volumetric changes. As sites matured,
volumetric reductions decreased. Sites captured as much large woody debris as was lost. While complexity is an extremely
important aspect of ecological function, artificial production of highly diverse and complex habitat features may lead to limited
longevity without natural rejuvenation.

Merz, J. E., J. D. Setka, et al. (2004). "Predicting benefits of spawning-habitat rehabilitation to salmonid (Oncorhynchus spp.) fry production in a regulated California river." Canadian Journal of Fisheries and Aquatic Sciences 61: 1433-1446.
Not available

Merz, J. E. and C. D. Vanicek (1996). "Comparative feeding habits of juvenile chinook salmon, steelhead, and Sacramento squawfish in the lower American River, California." California Fish and Game 82(4): 149-159.
We compared diets of juvenile chinook salmon, Oncorhynchus tshawytscha, steelhead, O. mykiss, and Sacramento squawfish, Ptychocheilus grandis, in the lower American River from February through July 1992 and 1993. Chinook salmon and steelhead fed primarily on chironomids (all stages), baetids (adults and nymphs), and hydropsychids (larvae and pupae); their diets overlapped significantly in May and June. Squawfish diet consisted mainly of corixid adults and chironomid larvae and did not overlap significantly with either chinook salmon or steelhead diets. Food habits changed somewhat as the season progressed and the fish increased in size. In 1993, chinook salmon and steelhead fed less than in the previous year and relied more on chironomids. We attribute these differences in diet to the major fluctuations in discharge and lower water temperatures that occurred in the lower American River that year.

Merz, J. E. a. J. D. S. (2004). "Evaluation of a Spawning Habitat Enhancement Site for Chinook Salmon in a Regulated California River." North American Journal of Fisheries Management 24: 397-407.
An evaluation of the effectiveness of a project to enhance spawning habitat for Chinook
salmon Oncorhynchus tshawytscha was conducted in the Mokelumne River, a regulated stream
in California's Central Valley. Approximately 976 m3 of clean river gravel (25–150 mm) was
placed in berm and gravel bar configurations along the 45-m enhancement site. Physical measurements
taken before and after gravel placement indicate that the project significantly increased
channel water velocities, intergravel permeability, and dissolved oxygen; reduced channel depths;
and equilibrated intergravel and ambient river temperatures. These positive benefits remained
throughout the 30-month monitoring period. Adult Chinook salmon began spawning at the previously
unused site within 2 months after gravel placement and continued to use the site during
the three spawning seasons encompassed by the study. Bed material movement was documented
by channel bathymetry surveys over two water years. Topographical channel surveys provide a
useful tool for monitoring bed material transport and layering redd locations on contour maps.
Although its usefulness in restoring salmon populations is poorly understood, gravel enhancement
can be an effective means for improving salmon spawning habitat in rivers where upstream dams
have effected low gravel recruitment.

Meseck, S. L. and G. A. Cutter (2006). "Evaluating the biogeochemical cycle of selenium in San Francisco Bay through modeling." Limnology and Oceanography 51(5): 2018-2032.
A biogeochemical model was developed to simulate salinity, total suspended material, phytoplankton biomass, dissolved selenium concentrations (selenite, selenate, and organic selenide), and particulate selenium concentrations (selenite + selenate, elemental selenium, and organic selenide) in the San Francisco Bay estuary. Model-generated estuarine profiles of total dissolved selenium reproduced

observed estuarine profiles at a confidence interval of 91-99% for 8 different years under various environmental conditions. The model accurately reproduced the observed dissolved speciation at confidence intervals of 81-98% for selenite, 72-91% for selenate, and 60-96% for organic selenide. For particulate selenium, model-simulated estuarine profiles duplicated the observed behavior of total particulate selenium (76-93%), elemental selenium (80-97%), selenite + selenate (77-82%), and organic selenide (70-83%). Discrepancies between model simulations and the observed data provided insights into the estuarine biogeochemical cycle of selenium that were largely unknown (e.g., adsorption/desorption). Forecasting simulations investigated how an increase in the discharge from the San Joaquin River and varying refinery inputs affect total dissolved and particulate selenium within the estuary. These model runs indicate that during high river flows the refinery signal is undetectable, but when river flow is low (70-day residence time) total particle-associated selenium concentrations can increase to > 2 mu g g(-1). Increasing the San Joaquin River discharge could also increase the total particle-associated selenium concentrations to > 1 mu g g(-1). For both forecasting simulations, particle-associated selenium was predicted to be higher than current conditions and reached levels where selenium could accumulate in the estuarine food web.

Mesick, C. (2001). The effects of San Joaquin River flows and Delta export rates during October on the number of adult San Joaquin chinook salmon that stray. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 139-162.

This report describes a two-part investigation of the effects of fall make-up pumping on straying of adult San Joaquin chinook salmon. The first part is a reevaluation of 1964 to 1967 data collected by Hallock and others (1970) on the migratory behavior of tagged and untagged adult San Joaquin salmon in the Delta. The second part is an evaluation of the recovery of adult salmon that were released in the San Joaquin basin as coded-wire tagged juveniles reared at the Merced River Fish Facility. There are three important results from Hallock and others (1970) regarding their migration analysis. First, adult salmon are migrating through the San Joaquin Delta near Prisoners Point primarily during October, the period when they are probably most susceptible to low flows and high exports. Second, the fish migrate slowly and do not arrive in the San Joaquin tributaries until about four weeks after they pass Prisoners Point, even when flows, exports, and dissolved oxygen concentrations near Stockton are suitable for migration. And third, migration rates of adult salmon are substantially higher when Vernalis flows exceed about 3,000 cfs and total exports are less than 100% of Vernalis flows. Although most of the tagged fish migrated into the Sacramento and Mokelumne basins when Vernalis flows were less than about 2,000 cfs and total exports exceeded 150% of Vernalis flows, there is uncertainty as to whether these were San Joaquin fish that strayed or Sacramento River fish that were captured in the San Joaquin on their way to the Sacramento River. The coded-wire-tag (CWT) recovery data may not have been appropriate for a straying analysis because there are no clear records of the number of fish examined for tags during the carcass surveys. Not all fish counted for the carcass survey were examined for tags. These recovery data are necessary to accurately compute the total number of adult salmon with tags in each river. A casual inspection of the CWT recovery data suggests that: (1) straying rates increased as the percentage of San Joaquin flow exported by the CVP and SWP pumping facilities increased and (2) the critical period is between 1 and 21 October. Furthermore, pulse flows from the San Joaquin tributaries, or a reduction of Delta exports that result in no more than a 300% export rate of San Joaquin flows at Vernalis for eight to twelve days in mid-October, are sufficient to keep straying rates below 3%. The results of these correlation analyses suggest that when more than 300% of Vernalis flow is exported over a ten-day period in mid-October adult San Joaquin chinook salmon stray to the Sacramento and eastside basins. However, further tests are needed due to the limitations of the existing data

Mesick, C. (2001). Studies of spawning habitat for fall-run chinook salmon in the Stanislaus River between Goodwin Dam and Riverbank from 1994 to 1997. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown.

Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 217-252.
The spawning habitat of fall-run chinook salmon (Oncorhynchus tshawytscha) was studied in the Stanislaus River between Goodwin Dam and Riverbank between 1994 and 1997 to evaluate whether habitat quality was potentially limiting the population and whether two restoration projects improved spawning conditions. Redd surveys in 1994 and 1995 indicated that spawning was concentrated in the riffles located in the 12-mile reach between Goodwin Dam and Orange Blossom Bridge . Most of the spawning (73%) occurred upstream of the riffles' crests where the streambed gradient was positive (for example, the tail of a pool). Sample areas were divided into the upper, middle, and lower portions of riffles to determine why the salmon used the upper areas.
Substrate samples collected from the upper six inches of the streambed indicated that predicted survival probabilities for chinook salmon eggs using Tappel and Bjornn's (1983) laboratory study averaged 75.6% in the reach above the Orange Blossom Bridge, 58.6% in the lower spawning reach between the bridge and town of Riverbank, and 95.4% at two restoration sites near the U.S. Army Corps of Engineers' Horseshoe Road park where gravel was added in 1994. Predicted egg survival probabilities averaged 73.2% upstream of riffle crests and 62.1% downstream of riffle crests at four natural riffles with pronounced crests.
Intragravel dissolved oxygen (DO) concentrations were relatively constant at 32 piezometer sites in the 12 study riffles during five surveys conducted at 10-day intervals in November and December 1995. The DO levels declined markedly in early February 1996 at nine sites shortly after runoff from four major storms increased base flows from 300 cfs to as much as 800 cfs for several days after each storm. Prior to the storms in November and December, intragravel DO concentrations were less than 5 ppm at six piezometer sites (19%) and less than 8 ppm at eleven sites (34%). Immediately after the fifth major storm in early February, intragravel DO concentrations were less than 5 ppm at 11 piezometer sites and less than 8 ppm at 16 sites (50%). Many of the sites where DO concentrations were low were associated with intragravel water temperatures that were between 1° and 6° F higher than surface temperatures. The elevated temperatures suggest the inflow of oxygen-poor groundwater. A high rate of groundwater inflow into the Stanislaus River 's riffles would explain the unexpectedly positive vertical hydraulic gradients upstream of the riffle crests measured at most of the piezometer sites in fall 1996.
A regression model of the average intragravel DO concentrations in November and December 1995 had an adj- R^2 of 0.80 with significant ($P \leq 0.05$) variables that include an index of groundwater inflow, abundance of Asian clams (Corbicula fluminea), percent fines <2 mm, and mean column water velocity. A model for the February 1996 DO concentrations had an adj- R^2 of 0.68 with significant variables that include the groundwater index and the percent fines <2 mm. Although streambed gradient indexes were not selected for the regression models, DO concentrations that were greater than 80% saturation in February 1996 usually occurred where the gradient was positive 2% or higher.
Not all restoration sites in the Stanislaus River where clean gravel was added were used by spawning salmon. Two riffles constructed with imported gravel from the Merced River were used by very few fish for three years even though intragravel DO levels were near saturation and spawning occurred in the immediate vicinity. After high flows deposited a large berm of native rock at the crest of one of these riffles in spring 1997, a relatively high number of salmon began spawning in the new substrate in fall 1997. In Goodwin Canyon , where gravel was lacking, many salmon quickly spawned in newly added gravel from the Stanislaus' floodplain placed in late summer 1997.

Messineo, J. (2009). Update on the Net Mouth Geometry Evaluation: Chipps Island Midwater Trawl. iEP Newsletter. 22: 2.

Messineo, J., M. Fish, D. Contreras, K. Hieb, and V. Afentoulis (2010). 2009 Fishes Annual Status and Trends Report for the San Francisco Estuary. IEP Newsletter. 23: 24.

Michaels, A. F. and A. R. Flegal (1990). "Lead in marine planktonic organisms and pelagic food webs." Limnology and Oceanography 35(2): 287-295.

The bioaccumulation of lead in biological ecosystems traditionally has been interpreted in terms of the atomic ratio of Pb to Ca. In marine planktonic ecosystem, however, most of the particulate Ca is skeletal and its amount variable among taxa. The Pb in plankton can be partitioned between skeletal and nonskeletal components. We develop a simple model based on the ratio of surface area to volume of organisms to make predictions about the relative importance of organism size and food-web interactions in the tranSFEr of Pb between trophic levels. For small organisms (< 270-mu m spherical radius or the equivalent surface: volume ratio), Pb concentration is determined almost entirely by surface area. For larger organisms, total body Pb will be a function of both the size of the prey and the distribution of Pb within tissues. The role of food-web interactions (e.g. grazing) in determining the amount of Pb in plankton of different sizes will only be important for large plankton and nekton, where very little of it is adsorbed on the animal surface.

Miklos, P. (2009). Delta Juvenile Fish Monitoring Program. IEP Newsletter. 22: 4.

Miller, A. W., A. L. Chang, et al. (2004). "A new record and eradication of the Northern Atlantic alga Ascophyllum nodosum (Phaeophyceae) from San Francisco Bay, California, USA." Journal of Phycology 40(6): 1028-1031.
A new record of the Northern Atlantic fucoid Ascophyllum nodosum (L.) Le Jolis (Knotted wrack) was discovered on a shoreline in San Francisco Bay, California during a survey of intertidal habitats in 2001-2002. The alga showed no signs of deterioration 2.5 months after its initial detection. The healthy condition, presence of receptacles with developing oogonia, potential for asexual reproduction, and ability to withstand environmental conditions, both inside the Bay and on the outer Pacific coast, prompted a multiagency eradication effort. Given the relatively small area of shoreline inhabited by the alga, in combination with its absence in 125 other surveyed locations, we decided that manual removal of the seaweed would be the most environmentally sensitive yet effective eradication approach. No A. nodosum has been detected at the site since December 2002, and the species is thought to have been locally eradicated. The site continues to be monitored to assess the success of the eradication efforts.

Miller, A. W., G. M. Ruiz, et al. (2007). "Differentiating successful and failed molluscan invaders in estuarine ecosystems." Marine Ecology Progress Series 332: 41-51.
Despite mounting evidence of invasive species' impacts on the environment and society, our ability to predict invasion establishment, spread, and impact are inadequate. Efforts to explain and predict invasion outcomes have been limited primarily to terrestrial and freshwater ecosystems. Invasions are also common in coastal marine ecosystems, yet to date predictive marine invasion models are absent. Here we present a model based on biological attributes associated with invasion success (establishment) of marine molluscs that compares successful and failed invasions from a group of 93 species introduced to San Francisco Bay (SFB) in association with commercial oyster transfers from eastern North America (ca. 1869 to 1940). A multiple logistic regression model correctly classified 83% of successful and 80% of failed invaders according to their source region abundance at the time of oyster transfers, tolerance of low salinity, and developmental mode. We tested the generality of the SFB invasion model by applying it to 3 coastal locations (2 in North America and 1 in Europe) that received oyster transfers from the same source and during the same time as SFB. The model correctly predicted 100, 75, and 86% of successful invaders in these locations, indicating that abundance, environmental tolerance (ability to withstand low salinity), and developmental mode not only explain patterns of invasion success in SFB, but more importantly, predict invasion success in geographically disparate marine ecosystems. Finally, we demonstrate that the proportion of marine molluscs that succeeded in the latter stages of invasion (i.e. that establish self-sustaining populations, spread and become pests) is much greater than has been previously predicted or shown for other animals and plants.

Miller, J., A. Gray, and J. Merz (2010). Quantifying the contribution of juvenile migratory phenotypes in a population of Chinook salmon Oncorhynchus tshawytscha. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento

Convention Center, Sacramento, California.
Chinook salmon is an anadromous species that varies in size at freshwater emigration, which is hypothesized to increase population resiliency under variable environmental regimes. In California’s Central Valley (USA), the majority of naturally spawned juveniles emigrate in 2 pulses: small juveniles (referred to as fry), typically ≤55 mm fork length (FL), emigrate from natal streams in February–March, whereas larger juveniles (smolts), typically >75 mm FL, emigrate in mid-April–May. In some river systems, there is a smaller pulse of emigrants of intermediate size (parr), typically 56 to 75 mm FL. Although the relative contribution of these migratory phenotypes to the adult population is unknown, management activities focus on survival of larger emigrants and most artificially produced fish (98%) are released from hatcheries at parr and smolt sizes. We reconstructed individual length at freshwater emigration for a sample of adult Central Valley Chinook salmon from 2 emigration years using chemical (Sr:Ca and Ba:Ca) and structural otolith analyses. The adult sample was comprised of individuals that emigrated as parr (mean = 48%), followed by smolts (32%) and fry (20%). Fry-sized emigrants likely represent natural production because fish ≤55 mm FL comprise <2% of the hatchery production. The distribution of migratory phenotypes represented in the adult sample was similar in both years despite apparent interannual variation in juvenile production, providing evidence for the contribution of diverse migratory phenotypes to the adult population. The contribution of all 3 migratory phenotypes to the adult population indicates that management and recovery efforts should focus on maintenance of life-history variation rather than the promotion of a particular phenotype.

Miller, L. (1974). "Mortality rates for California striped bass (Morone saxatilis) from 1965-1971." California Fish and Game 60: 157-171.
Harvest rates on M.saxatilis in the Sacramento-San Joaquin Estuary varied between 12 and 19% for the yrs 1965 to 1971. The mean harvest rate since 1965 (0.151) is 40% lower than the mean of 0.253 for the yrs 1958-64. Survival rates for 1965-71 varied from 61 to 69%. The mean survival rate (0.654) for this period was 21.3% higher than the 1958-64 mean of 0.539. A decline in angler success and angler effort appears related to a declining population. Exploitation rates have declined and survival rates increased apparently in response to lower fishing pressure. The bass tagged in 1965-66 averaged lower than bass tagged in previous yrs. Return rates were higher for female than for male.

Miller, L. W. (1972). "Migrations of sturgeon tagged in the Sacramento-San Joaquin Estuary." California Fish and Game 58: 102-106.
A total of 2,692 white sturgeon (Acipenser transmontanus) and 54 green sturgeon (Acipenser medirostris) were tagged in 1967 and 1968. Tag returns from white sturgeon indicate that the population inhabits the lower estuary during the summer, fall and winter. An apparent spawning migration occurs during late winter and spring. Two green sturgeon were recaptured at the mouth of the Columbia River, one in Washington, one at Santa Cruz and one in the estuary.

Miller, L. W. (1972). "White sturgeon population characteristics in the Sacramento-San Joaquin Estuary as measured by tagging." California Fish and Game 58: 94-101.

Miller, N. A., and J.H. Stillman (2013). "Seasonal and spatial variation in the energetics of the invasive clam Corbula amurensis in the upper San Francisco Estuary." Marine Ecology Progress Series 476: 129-139.
Predicting the impacts of invasive species on native communities requires an understanding
of the energy requirements of the community members and the strength and direction of
energy flows within the ecosystem. The Asian clam Corbula amurensis invaded the San Francisco
Estuary (SFE) in 1986 and is implicated in the decline of native fish species, by diverting pelagic
productivity to the benthos through filter feeding. We sought to characterize how energetic

demands of C. amurensis respond to natural seasonal and spatial variation in salinity, and how this response may be influenced by variation in temperature and food availability. We found that metabolic rates of C. amurensis vary seasonally and spatially within the estuary, but temperature, salinity, and food availability explain little of the variability. The insensitivity of metabolism to salinity suggests a re-evaluation of the importance of this environmental factor in determining the distribution of C. amurensis in the SFE. Though C. amurensis did hyperosmoregulate under low salinity conditions, the potential costs of this activity were not associated with changes in metabolic rate or energy stores (glycogen). Current knowledge suggests that under natural food, temperature, and salinity regimes in the SFE, the distribution of adult C. amurensis is not likely a consequence of the energetic costs of salinity tolerance. However, the role that food availability plays in modulating salinity tolerance, especially at different temperatures, deserves additional attention.

Miller, R., and R. Fujii (2010). Carbon storage, gas fluxes, and potential greenhouse gas effects of re-establishing wetlands on organic soils in the Sacramento-San Joaquin Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Draining wetlands in the Sacramento-San Joaquin Delta has caused oxidation and subsidence of the underlying organic soils. Following wetland re-establishment to two different water depths in 1997 (continuously flooded to ~25 cm and ~55 cm), we measured morning to midday gaseous carbon (C) fluxes, approximately monthly, by using vented chambers, for 6 years; and, estimated annual C storage for over a decade. Carbon dioxide (CO2) losses from the organic soil decreased as much as 10-fold shortly following flooding. Results from 14C isotope analysis showed that CO2 emitted from a neighboring agricultural field contained significant ‘old’ carbon, while wetland CO2 emissions were of a more modern origin. The shallower wetland showed more CO2 uptake and respiration than the more deeply flooded wetland; but, the deeper marsh emitted more methane (CH4). Thus, the shallower wetland had greater potential estimated greenhouse gas reduction benefits than the deeper wetland, despite similar estimates of annual carbon storage in areas with emergent marsh in both wetlands. Overall, CO2 uptake was enough greater than CH4 release in areas of emergent marsh that not only does re-establishing marshes in the Delta restore a strong carbon sink to the region, but greenhouse gas balance estimates demonstrated potential for significantly reduced radiative forcing. Furthermore, spatial variability in wetland environmental conditions appeared to affect decomposition dynamics and consequent CH4 losses, suggesting that wetland management can be used to minimize the greenhouse gas effects of re-established marshes in the Delta. In contrast, areas without emergent vegetation showed little carbon storage, and much lower uptake of CO2 compared to CH4 losses, such that the increased radiative forcing from these areas may not be counterbalanced by the benefits of mitigating the oxidative loss of organic soils with flooding.

Miller, S. (2010). A comparison between the Sacramento and Mississippi Delta levee systems. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The presentation will address the similarities and differences between two major US Delta Levee systems: the Sacramento-San Joaquin River Delta System in Northern California and the Mississippi River Delta Levee System in Louisiana. As a Water Resources Engineer for the Delta Levees and Environmental Engineering office at DWR, I have firsthand experience with the Sacramento system as a result of participating in various Delta infrastructure projects and field visits. A recent volunteering trip to assist with cleanup of the oil spill in the Gulf has given me

the opportunity to also experience the Mississippi system on a personal basis. Several photographs that I have taken of each system will be shown in this presentation, and topics discussed will be sustainability, environmental impacts, subsidence, and local issues.

Miller, W. J. (2011). "Revisiting Assumptions that Underlie Estimates of Proportional Entrainment of Delta Smelt by State and Federal Water Diversions from the Sacramento-San Joaquin Delta." San Francisco Estuary and Watershed Science 9(1).

Mills, C. E., and F. Sommer (1995). "Invertebrate introductions in marine habitats: Two species of Hydromedusae (Cnidaria) native to the Black Sea, Maeotias inexpectata and Blackfordia virginica, invade San Francisco Bay." Marine Biology 122(2): 279-288.

The hydrozoans Maeotias inexspectata Ostroumoff, 1896 and Blackfordia virginica Mayer, 1910, believed to be native to the Black Sea (i.e. Sarmatic) and resident in a variety of estuarine habitats worldwide, were found as introduced species in the Petaluma River and Napa River, California, in 1992 and 1993. These rivers are mostly-estuarine tributaries that flow into north San Francisco Bay. Both species appeared to be well-established in this brackishwater habitat. Salinities at the collection sites were about 11% during the summer, rising to nearly 20% in the early autumn and falling to near 0% in the winter. Large numbers of all sizes of both species of medusae were observed and collected, indicating that the hydroid stages of the life cycles of the two are also well-established in these rivers. In the Petaluma River, populations of both species were at maximum in late July, with numbers of individuals declining through August and into September; the Napa River was sampled only in October, and at that time only B. virginica was found. Examination of full guts of M. inexspectata and B. virginica medusae revealed that both species had fed nearly exclusively on small crustaceans, principally barnacle nauplii, copepods and their eggs and nauplii, and crab zoea larvae (M. inexspectata only). All the M. inexspectata medusae were males, indicating that the population has probably developed from the introduction of perhaps only a single male polyp or polyp bud. In spite of its inability to reproduce sexually, this population appears to be maintained by the prodigious ability of the polyp to bud and reproduce asexually, and is fully capable of invading additional low-salinity habitats from its present Petaluma River site. Male and female B. virginica medusae were collected in both the Petaluma River and the Napa River, indicating that B. virginica may have been introduced by either the polyp or medusa stage (or both), but that multiple individuals (of both sexes) must have arrived from another port in one or more invasions. As indicated for M. inexspectata, the B. virginica population will also probably seed new populations in San Francisco Bay and elsewhere. Based on its cnidome as well as the morphology of both medusa and polyp, M. inexspectata has been reclassified by moving it from the family Olindiidae, Limnomedusae, to the family Moerisiidae, Anthomedusae.

Mills, T. J., D.R. McEwan, and M.R. Jennings (1997). California salmon and steelhead: Beyond the crossroads. Pacific salmon and their ecosystems: Status and future options. D. Stouder, P. Bisson, and R. Naiman. New York, NY, Chapman and Hall: 91-111.

Mills, T. J. and F. Fisher (1994). "Central Valley anadromous sport fish annual run-size, harvest, and population estimates, 1967 through 1991."

Mills, T. J., D. R. McEwan, et al. (1997). California salmon and steelhead: Beyond the crossroads. Pacific salmon and their ecosystems: Status and future options. P. B. D. Stouder, and R. Naiman. New York, NY, Chapman and Hall: 91-111.

Mills, T. J. and J. T. Rees (2000). "New observations and corrections concerning the trio of invasive hydromedusae Maeotias marginata, (=M. inexpectata), Blackfordia virginica, and Moerisia sp in the San Francisco Estuary." Scientia Marina 64: 151-155.

New observations of Maeotias, Blackfordia, and Moerisia in low salinity waters of the San Francisco Bay estuary allow better understanding of the life

cycles and natural history of these three genera of invading hydrozoans. Maeotias inexpectata Ostroumoff, 1896 is found to be a junior synonym of Maeotias marginata (Modeer, 1791). Moreover, M. inexspectata Ostroumoff, 1896b is an incorrect subsequent spelling of M. inexpectata Ostroumoff, 1896a. The clear presence of marginal statocysts in the medusa of this species places it back in the family Olindiidae of the Limnomedusae. Polyps previously attributed to Maeotias in San Francisco Bay are now known to belong to a Moerisia sp., whose medusa has also recently been found in the estuary system. Solitary Moerisia polyps have been found in the field amongst the general fouling fauna on floating docks in the Napa River. Small simple primary polyps of M. marginata were obtained in the laboratory. Polyps of Blackfordia virginica have been found in abundance in the field covering the valves of nonindigenous barnacles in the Napa River and laboratory-cultured colonies are pictured here along with their newly-released and juvenile medusae.

Mineart, P., and R. Kulkarni (2010). Uncertainty analysis for geomorphic modeling. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The prediction of changes in long-term sedimentation (decadal time scale) are necessary if the impacts of projects that affect sedimentation in San Francisco Bay and Delta are to be adequately estimated. However, the prediction of sedimentation over these time scales is subject to a large amount of uncertainty. Causes of the uncertainty include unknown inputs, model approximations, errors in model parameters and method adopted for geomorphic analysis and the natural variability in sedimentation. This presentation presents a method for quantifying the uncertainty. The method is then applied to a proposed project in South San Francisco Bay as an example. An important component of estimating the uncertainty in the prediction of future long term sedimentation is to estimate the variance in the random error associated with the future prediction, which is assumed to be equal to the variance of the actual prediction of sedimentation. This value is estimated by dividing the simulation area in contiguous zones with similar habitat type, environmental conditions, and project impacts. The variance in the error is then estimated from point and average estimates of error within each zone based on hindcast simulations. The variance associated with project impacts can then be estimated based on the variance in the error in estimating future sedimentation and the expected correlation between no action and project conditions. An example application of the method is applied to a proposed projected in the South Bay. The results include a map of the Bay showing the expected changes in sedimentation, the forecast uncertainty and the coefficient of variation of the forecast error.

Mioni, C., and A. Paytan (2010). What controls Microcystis bloom and toxicity in the San Francisco Bay-Delta? 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The potential adverse impact of the bloom-forming cyanobacterium Microcystis on the estuary is large. Water from the northern region is used directly for drinking water and irrigation and the region is an important recreational area for sport fishing and water contact sports. The estuary is habitat for many anadromous, commercial and recreational fish including and is a feeding ground for marine mammals. The estuary also contains many threatened or endangered aquatic organisms and many of these species are declining (e.g. Delta Smelt). The coincident appearance of Microcystis and the decline of various pelagic organisms and their copepod preys in the freshwater sections of the Delta suggest that the presence of Microcystis is one of the factors responsible for the fishery decline since 2000. The increase of cyanobacteria in the Delta coincides with several changes that might favor their growth: increased water transparency, increased water temperature, increased specific conductance. These environmental changes appear to correlate also with the decline of pelagic fish species. Here, we will present preliminary results from monthly monitoring throughout the San Francisco Bay-Delta. This monitoring program was conducted in collaboration with the USGS water quality program and the DWR Environmental Monitoring Program and it includes spatial and temporal distribution of the liver-cancer promoting cyanobacterium, Microcystis, and its microcystin toxins. We will focus on our results from the 2009 and 2010 Microcystis blooms in the San Francisco Bay-Delta. These results suggest that surface water temperature is not only a driver of Microcystis growth but also of toxicity. Other factors (microbial interactions) that were not previously taken into account also appear to play a role in Microcystis toxicity.

Mirando, J., R. Padilla, M. Horn, J. DuBois, and J. Morinaka (2010). Evaluation of predation at salvaged fish release sites. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Predation on fish throughout the salvage process may reduce the benefit of the state and federal facilities that are operated to protect fish from entrainment into the export projects. Predation by piscivorous fish has long been suspected as having a major impact on the survival of fish in the salvage process. This study was designed to document the magnitude of predation that occurs during the final "release" phase of the CHTR process at the fish salvage facilities. Using multiple complementary sampling and observation methods (electrofishing, avian point counts, hydroacoustics, acoustic and Floy tagging, and DIDSON observations) the presence, abundance, and behavior of piscivores at 3 fish salvage release sites and 2 control sites in the central Delta were examined from August 2007 through March 2008. Results indicate that Sacramento pikeminnow (Ptychocheilus grandis), largemouth bass (Micropterus salmoides), striped bass (Morone saxatilis), cormorants (Phalacrocorax spp.), and gulls (Larus spp.) are the predominate predators of salvaged fish at the release sites. Predatory fish were observed throughout the study but were present in greater numbers during the summer and fall, correlating to periods when the greatest numbers of salvaged fish are released. An exact rate of predation mortality was not developed as the amount of biomass being salvaged and released may vary dramatically from day to day. However, study results suggest that predation at the release site could have a substantial effect on the number of fish surviving during the release phase of the salvage process depending on the season and quantity of biomass released. The results of this study include recommendations and guidelines to improve release operations and suggestions for physical changes to the existing release sites. The results will also aid in establishing guidelines for locating and designing future fish release sites and may have important implications for predator management efforts in the Delta.

Miyamoto, J. J., and R.D. Hartwell (2001). Population trends and escapement estimation of Mokelumne River fall-run chinook salmon (Oncorhynchus tshawytscha). Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 197-216.

In 1990 the East Bay Municipal Utility District (EBMUD) began a program to monitor the fall-run chinook salmon (Oncorhynchus tshawytscha) populations in the lower Mokelumne River using video and trapping at Woodbridge Dam and weekly redd surveys. Over the eight years of this monitoring program, the Mokelumne River fall-run chinook salmon escapement showed a trend of increased abundance of both hatchery and natural spawners. The 1997 estimated total spawning escapement (combined hatchery and natural run) was 10,175 compared to a spawning escapement of 497 in 1990 and the 57-year average escapement of 3,434 fish. The estimated natural spawning population fluctuated from a low of 369 in 1991 to a high of 3,892 fish (1,739.3 ± 1,384.9) in 1996. The percentage of natural spawners ranged between 31% to 90% (52.3 ± 19.9) of the total spawning escapement during the 1991–1997 period. Significant correlations were observed between the number of redds and total escapement ($R^2 = 0.941$, $P < 0.0001$) and the hatchery returns and total spawning escapement ($R^2 = 0.972$, $P < 0.001$). The later correlation was used to determine the accuracy of past spawning escapement estimates based upon a similar correlation using a narrower dataset. These results suggest accurate total spawning escapement estimates can be obtained from hatchery returns and from redd counts. Escapement estimates calculated from redd counts and compared with known estimates were accurate in the mid-range while those calculated from hatchery returns were accurate throughout the range of run sizes.

Modlin, R. F., and J.J. Orsi (1997). "Acanthomysis bowmani, a new species, and A. asperali, Mysidacea newly reported from the Sacramento-San Joaquin Estuary, California (Crustacea: Mysidae)." Proceedings of the Biological Society of Washington 110(3): 439-446.

Acanthomysis bowmani, a new species is described and named. Geographical

range is extended for A. asperia li (1964) to include the Sacramento-San Joaquin Estuary. Evidence indicates that both species were recently introduced into this estuarine system.

Modlin, R. F. and J. J. Orsi (2000). "Range extension of Acanthomysis hwanhaiensis Ii, 1964, to the San Francisco estuary, California, and notes on its description (Crustacea:Mysidacea)." Proceedings of the Biological Society of Washington 113: 690-695.
The range of Acanthomysis hwanhaiensis has been extended from Korea to the San Francisco Bay estuary, California, presumably as the result of ballast water discharge from ocean-crossing vessels. The species is described here because the previous description is out of print and difficult to obtain. Two verified exotic mysid species, and potentially a third, have previously been reported to inhabit the San Francisco Bay estuarine system.

Moisander, P. H., P. W. Lehman, et al. (2009). "Diversity of Microcystis aeruginosa in the Klamath River and San Francisco Bay delta, California, USA." Aquatic Microbial Ecology 57(1): 19-31.
Blooms of the toxin-producing cyanobacterium Microcystis aeruginosa have recently appeared in the Klamath River (KR) and San Francisco Bay delta (SFBD), California, USA. We investigated Microcystis diversity in these systems by targeting cpcBA (phycocyanin gene intergenic spacer and flanking regions) and mcyA gene (encodes part of a peptide synthetase cluster for production of the toxin microcystin). Distinct differences in Microcystis populations in the KR reservoirs (Copco and Iron Gate reservoirs) and SFBD were found in both gene loci, and diversity in the mcyA gene discriminated the populations in the 2 ecosystems entirely. The cpcBA sequences from KR fell into 2 main clusters, and were closely similar to sequences from North and South America, Europe, Asia, and Africa. The majority of the cpcBA sequences in populations from SFBD formed a unique group, while the remaining sequences were closely similar to those from KR. Salinity, soluble reactive phosphorus concentration, pH, water transparency, and NH4+ and NO3- + NO2- concentrations were significantly different in the 2 systems. The consistent differences in the 2 genetic markers between KR and SFBD populations suggest that Microcystis populations in the 2 watersheds have had limited connectivity or a different initial source population, or that environmental selection is creating distinct Microcystis populations in the eutrophic KR freshwater reservoirs and the saltwater influenced SFBD. Although Microcystis is globally distributed in temporal and subtropical climates, this study suggests local microdiversity exists and may be linked with environmental regulation.

Mongan, T. R., and B.J. Miller (1987). Water quality and water management: Sacramento-San Joaquin River System. Water quality in North American river systems. C. D. Becker, and D.A. Neitzel. Columbus, OH, Battelle Press. 117th Annual meeting of the American Fisheries Society, Winston-Salem, North Carolina, USA, September 1987: 85-115.

Mongan, T. R. and B. J. Miller (1992). Water quality and water management: Sacramento-San Joaquin River System. Water quality in North American river systems. a. D. A. N. C.D. Becker. Columbus, OH, Battelle Press. 117th Annual meeting of the American Fisheries Society, Winston-Salem, North Carolina, USA, September 1987: 85-115.

Monismith, S. G., J.R. Koseff, J.K. Thompson, C.A. O'Riordan, and H.M. Nepf (1990). "A study of model bivalve siphonal currents." Limnology and Oceanography 35(3): 680-696.
We carried out experiments studying the hydrodynamics of bivalve siphonal currents in a laboratory flume. Rather than use living animals, we devised a simple, model siphon pair connected to a pump. Fluorescence-based flow visualization was used to characterize siphon-jet flows for several geometric configurations and flow speeds. These measurements show that the boundary-layer velocity profile, siphon height, siphon pair orientation, and size of siphon structure all effect the vertical distribution of the excurrent flow downstream of the siphon pair and the

fraction of excurrent that is refiltered. The observed flows may effect both the clearance rate of an entire population of siphonate bivalves as well as the effciency of feeding of any individual. Our results imply that field conditions are properly represented in laboratory flume studies of phytoplankton biomass losses to benthic bivalves when the shear velocity and bottom roughness are matched to values found in the field. Numerical models of feeding by a bivalve population sould include an effective sink distribution which is created by the combined incurrent-excurrent flow field. Nearbed flows need to be accounted for to properly represent these benthic-pelagic exchanges. We also present velocity measurements made with a laser-Dopler anemometer (LDA) for a single configuration (siphons flush with bed, intel downstream) that show that the siphonal currents have a significant local effect on the properties of a turbulent boundary layer.

Monismith, S. G., J.R. Burau, and M. Stacey (1996). Stratification dynamics and gravitational circulation on northern San Francisco Bay. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science
AAAS: 123-153.

In this paper we discuss field observations and modeling results examining the connection between flow-induced stratification and gravitational circulation. We present simultaneous ADCP and top and bottom salinity records collected by the USGS showing that density-driven flows are highly intermittent, with strong gravitational circulation accompanying stratification episodes. Tidal variations in gravitational circulation appear to be linked to tide-induced vertical mixing and to the strain-induced periodic stratification (SIPS) that is typically found in Northern San Francisco Bay. Results obtained using a ID water column model suggest that there exists a critical condition where tidal mixing is unable to overcome the creation of stratification by advection. Variability of observed stratification is better explained by a parameter which explicitly considers SIPS, and thus which depends explicitly on the longitudinal salinity gradient, than it is by a similar parameter based on flow.

Monismith, S. G., W.J. Kimmerer, J.R. Burau, and M. Stacey (2002). "Structure and flow-induced variability of the subtidal salinity field in northern San Francisco Bay." Journal of Physical Oceanography 32(11): 3003-3019.

The structure of the salinity field in northern San Francisco Bay and how it is affected by freshwater flow are discussed. Two datasets are examined: the first is 23 years of daily salinity data taken by the U.S. Bureau of Reclamation along the axis of northern San Francisco Bay: the second is a set of salinity transects taken by the U.S. Geological Survey between 1988 and 1993. Central to this paper is a measure of salinity intrusion, X2: the distance from the Golden Gate Bridge to where the bottom salinity is 2 psu. Using X2 to scale distance, the authors find that for most flow conditions, the mean salinity distribution of the estuary is nearly self-similar with a salinity gradient in the center 70% of the region between the Golden Gate and X2 that is proportional to X2-1. Analysis of covariability of Q and X2 showed a characteristic timescale of adjustment of the salinity field of approximately 2 weeks. The steady-state response deduced from the X2 time series implies that X2 is proportional to riverflow to the 1/7 power. This relation, which differs from the standard 1/3 power dependence that is derived theoretically assuming constant exchange coefficients, shows that the upstream salt flux associated with gravitational circulation is more sensitive to the longitudinal salinity gradient than theory supposes. This is attributed to the strengthening of stratification caused by the stronger longitudinal salinity gradient that accompanies larger river flows.

Monismith, S. G., J. L. Hench, et al. (2009). "Thermal Variability in a Tidal River." Estuaries and Coasts 32(1): 100-110.

In this paper, we discuss observations of temperature variability in the tidal portion of the San Joaquin River in California. The San Joaquin River makes up the southern portion of the Sacramento San Joaquin Delta, the eastern end of San Francisco Bay. Observations made in August 2004 and August 2005 show significant diurnal variations in temperature in response to surface heat exchange. However, to account for observed changes in heat content a sizeable downstream heat flux (approximately 100 W m(-2)) must be added to the surface heat flux. To account for this flux via Fickian dispersion, a flow-dependent dispersion coefficient varying from 500 to 4,000 m(2) s(-1) is needed. These values are much larger than would be predicted for a river of this size, suggesting that the complex topology of the Delta greatly enhances longitudinal dispersion. Building on these observations, we present a simple theory that explores how the subtidal temperature field varies in response to changes in flow rate, dispersion, and heat exchange.

Monsen, N. E., J. E. Cloern, et al. (2007). "Effects of Flow Diversions on Water and Habitat Quality: Examples from California’s Highly Manipulated Sacramento-San Joaquin Delta." San Francisco Estuary and Watershed Science 5(3): art 2.

We use selected monitoring data to illustrate how localized water diversions from seasonal barriers, gate operations, and export pumps alter water quality across the Sacramento-San Joaquin Delta (California). Dynamics of water-quality variability are complex because the Delta is a mixing zone of water from the Sacramento and San Joaquin Rivers, agricultural return water, and the San Francisco Estuary. Each source has distinct water-quality characteristics, and the contribution of each source varies in response to natural hydrologic variability and water diversions. We use simulations with a tidal hydrodynamic model to reveal how three diversion events, as case studies, influence water quality through their alteration of Delta-wide water circulation patterns and flushing time. Reduction of export pumping decreases the proportion of Sacramento- to San Joaquin-derived fresh water in the central Delta, leading to rapid increases in salinity. Delta Cross Channel gate operations control salinity in the western Delta and alter the freshwater source distribution in the central Delta. Removal of the head of Old River barrier, in autumn, increases the flushing time of the Stockton Ship Channel from days to weeks, contributing to a depletion of dissolved oxygen. Each shift in water quality has implications either for habitat quality or municipal drinking water, illustrating the importance of a systems view to anticipate the suite of changes induced by flow manipulations, and to minimize the conflicts inherent in allocations of scarce resources to meet multiple objectives.

Monsen, N. E., J. E. Cloern, et al. (2002). "A comment on the use of flushing rate, residence time, and age as transport time scales." Limnology and Oceanography 47: 1545-1553.

Applications of transport time scales are pervasive in biological, hydrologic, and geochemical studies yet these times scales are not consistently defined and applied with rigor in the literature. We compare three transport time scales (flushing time, age, and residence time) commonly used to measure the retention of water or scalar quantities transported with water. We identify the underlying assumptions associated with each time scale, describe procedures for computing these time scales in idealized cases, and identify pitfalls when real-world systems deviate from these idealizations. We then apply the time scale definitions to a shallow 378 ha tidal lake to illustrate how deviations between real water bodies and the idealized examples can result from: (1) non-steady flow; (2) spatial variability in bathymetry, circulation, and transport time scales; and (3) tides that introduce complexities not accounted for in the idealized cases. These examples illustrate that no single transport time scale is valid for all time periods, locations, and constituents, and no one time scale describes all transport processes. We encourage aquatic scientists to rigorously define the transport time scale when it is applied, identify the underlying assumptions in the application of that concept, and ask if those assumptions are valid in the application of that approach for computing transport time scales in real systems.

Morgan, T. L., and D.H. Schoellhamer (2010). Sedimentation processes and turbidities favoring endangered fish northwestern Sacramento-San Joaquin River Delta Cache Slough Complex. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Morgan-King, T., and D.H. Schoellhamer (2010). Sedimentation processes and turbidities favoring endangered fish, northern Sacramento-San Joaquin River Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The Cache Slough region in the northern Delta has recently been recognized as key habitat for delta smelt, an endangered pelagic species endemic to the Upper San Francisco Estuary and Sacramento-San Joaquin Delta. This region includes a network of dead-end channels and a shallow flooded island (Liberty Island) with multiple levee breeches. We are investigating sedimentation processes that create and maintain high turbidity in the region, which is a key habitat characteristic for delta smelt. The study hypotheses are 1) during moderate-flow years, sediment is deposited in the area, and 2) during high-flow years, flow is unidirectional and much of the delivered sediment is transported through the region without deposition, 3) during low-flow and dry seasons little sediment is supplied to the region and sediment undergoes repeated cycles of resuspension and deposition as a trapped tidally-oscillatory mass, and 4) wind-wave resuspension of sediment on Liberty Island supplies sediment to the region. We continuously monitored water flow and turbidity at four sites in 2008 and 2009, and expanded our data collection efforts in 2010. From continuously deployed instrumentation combined with field samples, we calculated cross-sectional suspended-sediment flux. Preliminary results indicate 1) both the Ulatis Creek and Sacramento River watersheds supply significant sediment to the region, 2) a large portion of the first flush sediment pulse is trapped as a tidally-oscillating sediment mass, 3) strong winds resuspend sediment deposits and increase turbidity during the spring and summer, and 4) flood dominant tides transport some of this sediment further upstream into dead-end channels. The dead-end channels and shallow flooded island are rare habitats in the Delta that appear to retain sediment and have increased turbidity, making the Cache Slough Complex favorable habitat for delta smelt. Understanding the hydrologic and sediment dynamics are critical for restoration planning and Delta management efforts.

Morgan-King, T. L. a. D. H. S. (2012). "Suspended-Sediment Flux and Retention in a Backwater Tidal Slough Complex near the Landward Boundary of an Estuary." Estuaries and Coasts: 21.

Backwater tidal sloughs are commonly found at the landward boundary of estuaries. The Cache Slough complex is a backwater tidal region within the Upper Sacramento–San Joaquin Delta that includes two features that are relevant for resource managers: (1) relatively high abundance of the endangered fish, delta smelt (Hypomesus transpacificus), which prefers turbid water and (2) a recently flooded shallow island, Liberty Island, that is a prototype for habitat restoration. We characterized the turbidity around Liberty Island by measuring suspended-sediment flux at four locations from July 2008 through December 2010. An estuarine turbidity maximum in the backwater Cache Slough complex is created by tidal asymmetry, a limited tidal excursion, and wind-wave resuspension. During the study, there was a net export of sediment, though sediment accumulates within the region from landward tidal transport during the dry season. Sediment is continually resuspended by both wind waves and flood tide currents. The suspended-sediment mass oscillates within the region until winter freshwater flow pulses flush it seaward. The hydrodynamic characteristics within the backwater region such as low freshwater flow during the dry season, flood tide dominance,

Morinaka, J. (2010). Can delta smelt survive the CHTR phase of the fish salvage facilities? IEP 2010 Annual Workshop. Workshop presentation at the California State

University, Sacramento, Sacramento, CA.

Mortensen, W. E. (1987). Investigation of estuarine circulation in Suisun Bay.

Mosser, C., L. Thompson, and J. Strange (2010). Post-rescue monitoring of Butte Creek spring-run chinook salmon. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
During mid June of 2008 and 2009, some Butte Creek Spring-run Chinook salmon ceased volitional upstream migration towards critical upstream summer holding habitat, resulting in agency rescue operations where the stalled salmon were trapped and trucked upstream. In May 2009, regulatory agencies signed a memorandum regarding fish rescues, proposing a set of post-rescue strategies and acknowledging the lack of information concerning the fate of rescued fish. The monitoring pilot studies of 2008 and 2009 are a step toward better understanding the outcomes of fish rescues with respect to the strategy of immediate upstream release. In 2008, 352 adult spring-run Chinook salmon (~3.5% of the estimated return) were rescued and marked by pelvic fin clip. In 2009, 26 adult spring-run Chinook salmon (~1% of the estimated adult return) were rescued and implanted with esophageal radio tags and temperature loggers. In both years, fish were trucked 2.5 miles upstream. Pre-spawn and spawn carcass surveys during 2008 recovered 36 of the 352 marked fish, with the remaining 316 fish having an unknown fate. Radio tags for 23 of the 26 fish were recovered in 2009. In both years, greater than half of the recovered fish and tags were recovered within two weeks of release. Only five of the fish were recovered during the spawning season in 2008. All tag recoveries for 2009 were made within five weeks of the rescue release, significantly before the spawning season. In both years, pre-spawn mortality of recovered rescued fish was greater than 85% compared to ~5-10% for non-rescued fish.

Mount, J. and R. Twiss (2005). "Subsidence, sea level rise, and seismicity in the Sacramento-San Joaquin Delta." San Francisco Estuary and Watershed Science 3(1): Issue 1 Article 5.
Anthropogenic accommodation space, or that space in the Delta that lies below sea level and is filled neither with sediment nor water, serves as a useful measure of the regional consequences of Delta subsidence and sea level rise. Microbial oxidation and compaction of organic-rich soils due to farming activity is the primary cause of Delta subsidence. During the period 1900-2000, subsidence created approximately 2.5 billion cubic meters of anthropogenic accommodation space in the Delta. From 2000-2050, subsidence rates will slow due to depletion of organic material and better land use practices. However, by 2050 the Delta will contain more than 3 billion cubic meters of anthropogenic accommodation space due to continued subsidence and sea level rise. An Accommodation Space Index, which relates subaqueous accommodation space to anthropogenic accommodation space, provides an indicator of past and projected Delta conditions. While subsidence and sea level rise create increasing anthropogenic accommodation space in the Delta, they also lead to a regional increase in the forces that can cause levee failure. Although these forces take many forms, a Levee Force Index can be calculated that is a proxy for the cumulative forces acting on levees. The Levee Force Index increases significantly over the next 50 years demonstrating regional increases in the potential for island flooding. Based on continuing increases in the Levee Force Index and the Accommodation Space Index, and limited support for Delta levee upgrades, there will be a tendency for increases in and impacts of island flooding, with escalating costs for repairs. Additionally, there is a two-in-three chance that 100-year recurrence interval floods or earthquakes will cause catastrophic flooding and significant change in the Delta by 2050. Currently, the California Bay-Delta Authority has no overarching policy that addresses the consequences of, and potential responses to, gradual or abrupt landscape change in the Delta.

Moyle, P. B., J.J. Smith, R.A. Daniels, T.L. Taylor, D.G. Price, and D.M. Baltz (1982). "Distribution and ecology of stream fishes of the Sacramento-San Joaquin drainage system, California." University of California Publications in Zoology 115: 1-256.

Moyle, P. B., and D.M. Baltz (1985). "Microhabitat use by an assemblage of

California stream fishes: Developing criteria for instream flow determinations." Transactions of the American Fisheries Society 114: 695-704.
Microhabitat requirements were determined for eight species of native California stream fishes: rainbow trout Salmo gairdneri; Sacramento sucker Catostomus occidentalis; Sacramentos quawfish Ptychocheilusg randis; hardhead Mylopharodon conocephalus;California roach Hesperoleucus symmetricus;speckled dace Rhinichthyso sculus; rule perch Hysterocarpustr aski; and riffle sculpin Cottus gulosus. Two or three size classes were evaluated for each species. Each species had a preferred microhabitat (defined on the basis of depth, velocity, substrate), as did each size class within each species, but there was much similarity in microhabitat use within and among species. The amount of microhabitat available to each species differed in three stream reaches in which availability was quantified, but the differences were not enough to explain the differences in composition of the fish assemblage found at each site. This study indicates that recommendations for instream flows should be based on microhabitat use data collected on site together with habitat availability data. Even on-site data should be used cautiously because intraspecific interactions and changes in a stream's physical characteristics, especially in its temperature regime, may cause unexpected shifts in microhabitat use.

Moyle, P. B. (1986). Fish introductions into North America: patterns and ecological impact. Ecology of biological invasions of North America and Hawaii. H. A. Mooney, and J.A. Drake. New York, NY, Springer-Verlag: 27-43.

Moyle, P. B., R.A. Daniels, B. Herbold, and D.M. Baltz (1986). "Patterns in distribution and abundance of a non-coevolved assemblage of estuarine fishes in California." Fisheries Bulletin 84: 105-117.
The patterns of distribution and abundance of the fishes of Suisun Marsh, a portion of the Sacramento San Joaquin estuary in central California, were studied over a 54-month period. Total fish abundance in the marsh exhibited strong seasonality; numbers and biomass were lowest in winter and spring and highest in late summer. Freshwater inflow was highest in the winter and lowest in late summer, when salinities and temperatures were highest. Twenty-one species were collected on a regular basis; the 10 most abundant were Morone saxatilis, Pogonichthys macrolepidotus, Gasterosteus aculeatus, Hysterocarpus traski, Cottus asper, Spirinchus thaleichthys, Acanthogobius flavimanus, Catostomus occidentalis, Leptocottus armatus, and Platichthys stellatus. Another 21 species occurred in small numbers on an irregular basis. Twenty of the 42 species had been introduced to California since 1879. Of the 21 common species, 14 were residents, 4 were winter seasonals, and 3 were spring/summer seasonals. The resident species fell into two groups: a group of native species that were concentrated in small dead-end sloughs and a group of native and introduced species that were most abundant in the larger sloughs. The seasonal species were also a mixture of native and introduced species. Total fish abundance and species diversity declined through the study period, which seemed to be related to strong year classes of some species early in the study and the prevalance of freshwater conditions late in the study. The structure of the fish assemblage was fairly consistent over the study period but changes are expected in the near future. The structure of the Suisun Marsh fish assemblage was similar to that found in other river-dominated estuaries, despite the mixture of native and introduced species.

Moyle, P. B., J.E. Williams, and E.D. Wikramanayake (1989). "Fish species of special concern in California." California Department of Fish and Game.

Moyle, P. B., and J.E. Williams (1990). "Biodiversity loss in the temperate zone: Decline of the native fish fauna of California." Conservation Biology: the journal of the Society for Conservation Biology 4(3): 275-284.
In proportion to the entire fauna, loss of species may be as great in temperate regions as in tropical regions. To test the validity of this statement we analyzed the status of the native fish fauna of California, using a methodology that quantifies expert knowledge. Of 113 native taxa, 6 percent are extinct, 12 percent are officially listed as threatened or endangered 6 percent deserve immediate listing I7 percent may need listing soon, 22 percent show declining populations but

are not yet in serious trouble, and 36 percent appear to be secure. Much of the faunal decline has taken place in recent years; it has included unexpectedly rapid declines of once abundant species. Fish taxa in serious trouble are most likely to be (1) endemic to California, (2) restricted to a small area, (3) occupants of just one drainage basin, (4) part of a fish assemblage of less than five species, and (5) found in isolated springs, warm water streams, or big rivers. Water diversions and introduced species, acting in concert, seem to be the principal causes of the decline of the native fauna, although other types of habitat degradation have contributed as well. The situation in California, with its high degree of endemism (60 percent), may be regarded as extreme but fish faunas in other temperate regions show signs of being nearly as stressed. It is likely that the situation with fish reflects a more general decline of the biota of temperate regions of the world.

Moyle, P. B., B. Herbold, D.E. Stevens, and L.W. Miller. (1992). "Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California." Transactions of the American Fisheries Society 121(1): 67-77.
The delta smelt Hypomesus transpacificus is endemic to the upper Sacramento-San Joaquin estuary. It is closely associated with the freshwater-saltwater mixing zone except when it spawns in fresh water, primarily during March, April, and May. The delta smelt feeds on zooplankton, principally copepods. Its dominant prey was the native copepod Eurytemora affinis in 1972-1974 but the exotic copepod Pseudodiaptomus forbesi in 1988. Because the delta smelt has a 1-year life cycle and low fecundity (mean, 1,907 eggs/female), it is particularly sensitive to changes in estuarine conditions. Tow-net and midwater trawl samples taken from 1959 through 1981 throughout the delta smelt's range showed wide year-to-year fluctuations in population densities. Surveys encompassing different areas showed declines in different years between 1980 and 1983. After 1983, however, all studies have shown that the populations remained at very low densities throughout most of the range. The recent decline of delta smelt coincides with an increase in the diversion of inflowing water during a period of extended drought. These conditions have restricted the mixing zone to a relatively small area of deep river channels and, presumably, have increased the entrainment of delta smelt into water diversions. Restoration of the delta smelt to a sustainable population size is likely to require maintenance of the mixing zone in Suisun Bay and maintenance of net seaward flows in the lower San Joaquin River during the period when larvae are present.

Moyle, P. B., and R.A. Leidy (1992). Loss of biodiversity in aquatic ecosystems: Evidence from fish faunas. Conservation biology: The theory and practice of nature conservation, preservation, and management. P. L. Fiedler, and S. K. Jain. New York, NY, Chapman & Hall: 127-170.
Fishes are appropriate indicators of trends in aquatic biodiversity because their enormous variety reflects a wide range of environmental conditions. Fish also have a major impact on the distribution and abundance of other organisms in waters they inhabit. Examination of trends in freshwater fish faunas from different parts of the world indicate that most faunas are in serious decline and in need of immediate protection. Species most likely to be threatened with immediate extinction are either specialized for life in large rivers or are endemic species with very small distributions. We conservatively estimate that 20% of the freshwater fish species of the world (ca. 1800 species) are already extinct or in serious decline. Evidence for serious declines in marine fishes is limited largely to estuarine fishes, reflecting their dependence on freshwater inflows, or to fishes in inland seas.

Moyle, P. B. (1993). "Saving California's salmon: The legacy of Ishi." TROUT, The Journal of Coldwater Fisheries Foundation Summer: 14-17.

Moyle, P. B. (1994). "The decline of anadromous fishes in California." Conservation Biology: the journal of the Society for Conservation Biology 8(3): 869-870.
The universal decline of anadromous fishes in California reflects the general decline in the quality of aquatic environments. However, each species may be declining for a different combination of anthropogenic reasons in conjunction with a period of naturally stressful conditions in both fresh and salt water.

Moyle, P. B., and T. Light (1996). "Biological invasions of fresh water: empirical rules and assembly theory." Biological Conservation 78(1-2): 149-161.
Because the integrity of aquatic ecosystems is being challenged worldwide by invading species, there is a growing need to understand the invasion process and to predict the success and effects of invading species. Case histories of fish invasions in streams, lakes, and estuaries indicate that invading species and systems being invaded interact in idiosyncratic ways that are often hard to predict, largely because of the role of environmental variability in determining the outcomes of invasions. We nevertheless present a conceptual model of aquatic invasions and a dozen empirically-derived rules that seem to govern most aquatic invasions. While these rules are limited in their usefulness, they do seem to have more predictive value than rules derived from community assembly theory.

Moyle, P. B., and T. Light (1996). "Fish invasions in California: do abiotic factors determine success?" Ecology 77(6): 1666-1670.

Moyle, P. B., P.M. Marchetti, J. Baldrige, and T.L. Taylor (1998). "Fish health and diversity: Justifying flows for a California stream." Fisheries 23(7): 6-15.
Efforts by a citizen's group, Putah Creek Council, to improve the flow regime of a California stream for ecosystem, aesthetic, recreational, educational, and research purposes led to a successful court trial in which fish conservation played a key role. A major issue around which the trial revolved was the proper interpretation of a section (5937) of the California Fish and Game Code, which states that fish must be maintained in "good condition" below a dam. We defined good condition to mean there had to be healthy individual fish in healthy populations that were part of healthy biotic communities. This definition resulted in a conceptual model for instream flows for the creek that favored native resident and anadromous fishes. The stream flow recommendations from this model had four components: living space flows for the entire creek, resident native fish spawning and rearing flows, anadromous fish flows, and habitat maintenance flows. The trial judge, in attempting to balance competing demands for the water, ordered the implementation of only the first two recommendations. The order has been appealed by the water interests, but regardless of the final outcome, the court's decision reflects the growing public interest in protecting streams, the need for innovative use of existing legal tools to try to protect aquatic resources, and the importance of biological information in developing flow recommendations for complex fish assemblages.

Moyle, P. B. (2002). Inland fishes of California. Berkeley, University of California Press.

Moyle, P. B., R.D. Baxter, T.R. Sommer, T.C. Foin, and S.A. Matern (2004). "Biology and population dynamics of Sacramento splittail (Pogonichthys macrolepidotus) in the San Francisco Estuary: A review." San Francisco Estuary and Watershed Science 2(2): 43.
The Sacramento splittail (Pogonichthys macrolepidotus) is a cyprinid fish endemic to the Central Valley of California with a range that centers on the San Francisco Estuary. It is a state Species of Special Concern and was only recently (2003) delisted as a threatened species by the U. S. Fish and Wildlife Service. Splittail live 7-9 years, tolerate a wide range of environmental conditions, and have high fecundity. Typically, adults migrate upstream in January and February and spawn on seasonally inundated floodplains in March and April. In May the juveniles migrate back downstream to shallow, brackish water rearing grounds, where they feed on detritus and invertebrates for 1-2 years before migrating back upstream to spawn. Seven long-term sampling programs in the estuary indicate that the splittail population is maintained by strong year classes resulting from successful spawning in wet years, although some spawning occurs in all years. Modeling shows them to be resilient, but managing floodplains to promote frequent successful spawning is needed to keep them abundant. Additionally, it is important to provide safe migration corridors between spawning and rearing grounds as well as abundant high-quality brackish water rearing habitat. Key research needs are (1) to examine how the timing, magnitude, and duration of high flows contribute to the generation

of strong year classes, (2) to describe differences in young of year survival on the floodplain and in river margins from hatching to down-river migration, (3) explore the possible trophic effects of new invaders such as the overbite clam and Siberian prawn, and (4) determine the response of splittail populations to climate change and sea level rise.

Moyle, P. B., J. Hobbs, and T. O'Rear (2012). Tidal marsh fishes of the San Francisco Estuary Ecology, conservation and restoration of tidal marshes: The San Francisco Estuary. A. Palaima. Berkeley, University of California Press.

Moyle, P. B., P. K. Crain, et al. (2007). "Patterns in the Use of a Restored California Floodplain by Native and Alien Fishes." San Francisco Estuary and Watershed Science 5(3): Issue 3 Article 1.
ishes were sampled on the restored floodplain of the Cosumnes River in Central California in order to determine patterns of floodplain use. The floodplain was sampled for seven years (1998-2002, 2004-2005) during the winter-spring flooding season. The fishes fell into five groups: (1) floodplain spawners, (2) river spawners, (3) floodplain foragers, (4) floodplain pond fishes, and (5) inadvertent users. Eight of the 18 abundant species were natives, while the rest were aliens. There was a consistent pattern of floodplain use, modified by timing and extent of flooding. The first fishes to appear were floodplain foragers, inadvertent users, and juvenile Chinook salmon (river spawners). Next were floodplain spawners, principally Sacramento splittail and common carp. At the end of the season, in ponds of residual water, non-native annual fishes, mainly inland silverside and western mosquitofish, became abundant. Adult spawners left when inflow decreased; their juveniles persisted as long as flood pulses kept water levels up and temperatures low. Juvenile splittail and carp quickly grew large enough to dominate floodplain fish samples, along with smaller numbers of juvenile Sacramento sucker and pikeminnow (river spawners). Such juveniles left the Relatively few fishes that used the floodplain for spawning or rearing became stranded, except late season alien fishes. Most alien fishes had resident populations in adjacent river, sloughs, and ditches and were not dependent on the floodplain for persistence. This indicates that Central Valley floodplains managed to favor native fishes should have the following char- acteristics: (1) extensive early season flooding, (2) complete drainage by the end of the flooding season, (3) few areas with permanent water, (4) a mosaic of physical habitats, (5) regular annual flooding but with high variability in flood regime.

Moyle, P. B., P. K. Crain, et al. (2003). "Alien fishes in natural streams: fish distribution, assemblage structure, and conservation in the Cosumnes River, California, USA." Environmental Biology of Fishes 68(2): 143-162.
The Cosumnes River is the largest stream without a major dam on its mainstem in the Sacramento - San Joaquin drainage, central California, U. S. A. We studied its fishes over a 3-year period to answer the following questions: (1) Was the native fish fauna still present? (2) Why were alien fishes so abundant in a river system with a 'natural' flow regime, which elsewhere has been shown to favor native fishes? (3) Were there assemblages of fishes that reflected environmental differences created by the underlying geology? (4) Were there features of the watershed that consistently favored native fishes or that could be managed to favor native fishes? Of the 25 species collected, 17 were alien species; 14 species (five native) were abundant or widely distributed enough to use in detailed analyses. Of the native species, only rainbow trout, Oncorhynchus mykiss, still occupied much of its native range in headwater streams. Other native species have been extirpated or persisted mainly above barriers to alien invasions. The most widely distributed alien species was redeye bass, Micropterus coosae, previously unknown from the river, whose abundance was associated with low-numbers of native species. Other aliens were found primarily in low-land habitats on the valley floor or foothills. Canonical Correspondence Analysis indicated that both native and alien species located on environmental gradients determined largely by elevation, temperature, flow, and emergent vegetation, but the associations with these variables were not strong. While most alien fishes were found in lowland sections of river flowing through agricultural regions, the general relationships between species abundance and landscape-level variables were weak. Assemblages of fishes were poorly defined

mixtures of native and alien species. The strikingly distinct geological regions of the basin no longer supported distinct fish assemblages. Species distributions were highly individualistic, reflecting dynamic patterns of introductions, invasions, and local extinctions, as well as physiological tolerances and life history patterns. Most native fishes are likely to persist in the Cosumnes River only if summer flows are increased and if populations above natural barriers are protected from further invasions by alien species, especially redeye bass. General conclusions from this study include: (1) altered habitats can support native species under some circumstances; (2) new fish assemblages with characteristics of 'natural' communities are likely to develop in invaded systems; (3) restoring flow regimes to favor native fishes may require restoring minimum summer flows as well as high channel-forming flows. However, reversing or even reducing, the impact of the predatory redeye bass, pre-adapted for California streams, is probably not possible.

Moyle, P. B. and J. A. Israel (2005). "Untested assumptions: effectiveness of screening diversions for conservation of fish populations." Fisheries 30: 20-28.
Diversions from streams are often screened to prevent loss of fish. Because construction of fish screens competes for scarce dollars with other fish conservation projects, the widely accepted premise that fish screens protect fish populations merits thorough examination. We reviewed literature on fish screen projects in California’s Central Valley, where there are over 3,000 diversions. We found few studies that even attempted to evaluate the effectiveness of screens in preventing losses of fish, much less declines in fish populations. The limited published literature suggests that this lack of evaluation is typical throughout the western United States, despite millions of dollars spent annually on screens and their maintenance. Nevertheless even small diversions can be important sources of fish mortality, given their large number and the combined volume of water they divert. The impact on fish populations of individual diversions is likely highly variable and depends upon size and location, as demonstrated by evaluations of cooling water intakes for power plants. Studies are needed to determine which diversions have the greatest impact on fish populations in order to set priorities for screening, to make the best use of limited public funds available for restoration and conservation, and to provide scientific support for effective screening policies.

Moyle, P. B., J. R. Lund, et al. (2010). "Habitat Variability and Complexity in the Upper San Francisco Estuary." San Francisco Estuary and Watershed Science 8(3).

Moyle, P. B. and M. P. Marchetti (2006). "Predicting invasion success: Freshwater fishes in California as a model." Bioscience 56(6): 515-524.
The location, size, and geography of California, combined with extensive knowledge of successful and failed fish invasions, provide an unusual opportunity to test predictors of invasion success. Our analyses show that different characteristics of alien fishes are important at different stages of the invasion process. We found no set of characters that predicted success for all fish invasions, although some characters increase the probability of success. The factors that best predict invasion success are (a) a history of successful establishment outside the species' native range; (b) characters that promote success at multiple stages of the invasion process (e.g., high physiological tolerance); (c) invaded habitat that more or less matches the alien's native habitat; (d) high fish species richness, including other alien fishes; and (e) propagule size exceeding 100 individuals. The difficulty of predicting the invasion success of alien species points to the need to allow only introductions that have proved to be nonharmful and to take quick action to prevent the spread of new invaders.

Mueller-Solger, A. (2010). IEP Science Highlights 2009-2010. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Mueller-Solger, A. B., A. D. Jassby and D. C. Mueller-Navarra. (2002). "Nutritional quality of food resources for zooplankton (Daphnia) in a tidal freshwater system (Sacramento-San Joaquin River Delta)." Limnology and Oceanography 47(5): 1468-1476.
We examined the relative nutritional values of natural phytoplankton and particulate detritus for zooplankton growth in a detritus-rich environment. Seston was collected seasonally from four different habitat types in a tidal freshwater system and fed to juvenile Daphnia magna under controlled culture conditions by use of a flow-through design. Seston particulate organic carbon (POC) and chlorophyll a contents ranged from ~330 to 3,800 mg L21 POC and 1.4 to 45 mg L21 Chl a. A partial residual analysis revealed that detrital carbon concentrations were only weakly related to Daphnia growth, whereas Chl a proved to be highly predictive of Daphnia growth rates across all investigated habitat types. Overall, habitat type had a strong effect on growth rates, whereas season of seston collection did not, but differences among habitats could be attributed to differing Chl a concentrations. The results from this study imply that, even in systems with overwhelming amounts of detrital carbon from a variety of sources, nutritional factors associated with phytoplankton can be dominant in regulating zooplankton growth.

Mulvey, B., D. Smith, R. Abbott, and A. Goodwin (2010). Forecasting fish response to levee repair features of the Sacramento River Bank Protection Project. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The Sacramento River Bank Protection Project was authorized to protect more than 1700 kilometers of levees and flood control facilities. A key component of the levee repair work is the incorporation of environmental features that restore riparian and fish habitat function. Presently, the primary tool for planning the incorporation of these features is the Standard Assessment Methodology (SAM). SAM uses a combination of field data, riparian and geomorphologic models to assess proposed project impacts, but there still remains uncertainty regarding the function and value of the incorporated features for benefiting the target fish species. To improve the assessment ability of SAM and better understand the benefits of the constructed habitat features, we are collecting two-dimensional fish movement data using acoustic tags and developing models supporting the use of Eularian Lagrangian Agent Method (ELAM). The ELAM extends the use of computational fluid dynamics models because virtual fish are released inside the model field where they can react to habitat alterations such as levee repairs. The fish movement tracking data can be used to calibrate and validate ELAM output, which can be used to model generalized results to produce site-specific habitat suitability curves that can be incorporated into the SAM and improve assessment and forecasting capabilities. The combination of the SAM with ELAM is a promising approach that could improve the planning and execution of ecological projects.

Mulvey, B., J. Hoover, J. Kilgore, and K. Boysen (2010).
Population assessment of green sturgeon in the Sacramento River Bank Protection Proj ect. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Munevar, A. (2010). Incorporating climate variability, change, and model uncertainty in scenarios for California water planning. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Climate change projections derived from global climate models are becoming more widely used in basin-scale water planning and management. These model projections consistently indicate accelerated warming throughout the 21st century, but the degree of warming varies considerably between models and emission scenarios. For most of California, even greater uncertainty exists in projections of precipitation with some models indicating directionally inconsistent trends. Selection of appropriate representative scenarios of future climate variability and

change is important for regional and basin-scale studies. Use of the multi-model ensemble has been shown to be superior to any individual model projection largely through reduction in the “noise” and multi-decadal variability inherent in individual projections. While these findings suggest that as many projections of the ensemble as is possible should be considered, for many applications it is impractical to simulate the impacts of tens to a hundred of climate projections on water resources involving hydrological, biological, estuarine, and fisheries studies for a broad suite of water management alternatives. This paper presents a hybrid technique for climate scenario selection that reflects the full range of uncertainty in climate projections through the use of sub-ensembles. The technique allows for the selection of statistically-representative climate scenarios, derived from over 100 downscaled climate projections, which maintain superiority over individual scenarios while reducing the number of projections needed for complex water management studies. This technique is being applied in planning studies for the Bay Delta Conservation Plan.

Munevar, A., and C. Chilmakuri (2010). Regional hydrologic and water management system responses to climate futures. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Recent observed and projected changes in climate and sea level have substantial influence on the regional watershed processes and water management in the Central Valley and Bay-Delta. Not all watersheds are influenced in the same manner and degree. Hydrologic modeling, using the Variable Infiltration Capacity (VIC) hydrology model, of the Sacramento and San Joaquin Valley watersheds has been performed for a range of climate scenarios selected for the Bay Delta Conservation Plan (BDCP). The VIC modeling results suggest important regional and seasonal trends in factors such as precipitation, temperature, snowpack development and melt, soil moisture, and evapotranspiration. Spatial and temporal changes in these parameters, and their culminating net effect on timing and magnitude of streamflow, will be discussed. At the same time, sea level change scenarios and hydrodynamic and water quality modeling suggest a significant changes to tidal and salinity regimes within the Delta. Water management, however, must consider changes to the “system” which are impacted by upstream changes from climate, hydrology, and river water quality conditions; and downstream changes in ocean and estuary responses. The management of this system under a range of climate futures is being analyzed in the BDCP. Integrated physical modeling is being conducted to better inform long-term water management of the Central Valley system and provide insights into adaptive management of the program to balance water supply and ecosystem needs.

Murray, A. E., J. T. Hollibaugh, et al. (1996). "Phylogenetic compositions of bacterioplankton from two California estuaries compared by denaturing gradient gel electrophoresis of 16S rDNA fragments." Applied and Environmental Microbiology 62: 2676-2680.
The phylogenetic compositions of bacterioplankton assemblages from San Francisco Bay and Tomales Bay, Calif., differed substantially when analyzed by PCR-denaturing gradient gel electrophoresis; these differences are consistent with the results of previous studies demonstrating differences in their metabolic capabilities. PCR-denaturing gradient gel electrophoresis analysis of complex microbial assemblages was sensitive and reliable, and the results were reproducible as shown by experiments with constructed and naturally occurring assemblages.

Murrell, M. C., and J.T. Hollibaugh (1998). "Microzooplankton grazing in northern San Francisco Bay measured by the dilution method." Aquatic Microbial Ecology 15: 53-63.
Microzooplankton (defined herein as phagotrophs <200 µm) grazing was studied in northern San Francisco Bay, California, USA, from September 1993 to July 1994 using the dilution method. The focus of the study was the estuarine turbidity maximum zone of northern San Francisco Bay (Suisun Bay), though some experiments were also performed in southern San Francisco Bay and Tomales Bay. Three microzooplankton prey items were examined: phytoplankton (as chlorophyll a), cyanobacteria, and bacterioplankton (i.e. non-chlorophyll containing bacteria). Statistically significant grazing rates were observed in 5 of 31 northern San Francisco Bay experiments over 7 dates spanning 10 mo. Average grazing rates on

phytoplankton, cyanobacteria and bacterioplankton were 0.06, 0.00, and 0.22 d-1 respectively. Grazing rates were statistically significant in 5 of 7 southern San Francisco Bay experiments on 3 dates. Average grazing rates on phytoplankton and cyanobacteria were 0.41 and 1.84 d-1 respectively. Grazing rates were statistically significant in 4 of 4 Tomales Bay experiments performed on 1 date, averaging 0.69 and 0.75 d-1 on phytoplankton and bacterioplankton respectively. The low grazing rates in northern San Francisco Bay suggest that microzooplankton may not play a pivotal role in controlling prey biomass, although this interpretation is complicated by the possibility that one or more of the dilution method assumptions may not hold in this environment. We hypothesize that the introduced Asian clam Potamocorbula amurensis may be controlling the biomass of microzooplankton, their prey, or both. A review of the literature indicated that the dilution method regularly yields statistically non-significant grazing rates, suggesting that our results are not unique.

Murrell, M. C., J.T. Hollibaugh, M.W. Silver, and P.S. Wong (1999). "Bacterioplankton dynamics in northern San Francisco Bay: Role of particle association and seasonal freshwater flow." Limnology and Oceanography 44(2): 295-308.

Bacterioplankton abundance and metabolic characteristics were observed in northern San Francisco Bay, California, during spring and summer 1996 at three sites: Central Bay, Suisun Bay, and the Sacramento River. These sites spanned a salinity gradient from marine to freshwater, and sampling occurred during a period of seasonally declining river flow. The microbial measures included radio-labeled amino acid uptake (L-leucine, L-proline, L-serine), ectoenzyme activity (aminopeptidase and β-D-glucosidase), and bacterial abundance using 1-μm filters to separate free from particle-associated bacteria. A seasonal decline in all bacterial metabolic measures was observed at all stations, suggesting that a system-wide variable may be important in controlling bacterial activity. One such variable is freshwater flow into the Bay (as a proxy for organic matter flux), which positively covaried with all metabolic measures. A sharp decline in particle-associated bacteria was also observed in Suisun Bay and the Sacramento River between July and August. This decline may have been due to combined effects of declining nutritive value of the aging particles and increasing grazing pressure by benthic filter feeders. Aminopeptidase activity was positively related with increasing salinity, and β-D-glucosidase was negatively correlated with increasing salinity, indicating a gradient in the relative quality of organic matter from carbohydrate-rich riverine to protein-rich oceanic material. Overall, Suisun Bay had the highest mean proportion of particle-associated bacteria (49%), followed by Sacramento River (36%) and Central Bay (11%). Particles were the sites of enhanced ectoenzyme activity but not amino acid incorporation. Bacteria may be actively dissolving the particulate organic matter, but their growth rates on particles are not significantly enhanced.

Murrell, M. C., and J.T. Hollibaugh (2000). "Distribution and composition of dissolved and particulate organic carbon in northern San Francisco Bay during low flow conditions." Estuarine, Coastal and Shelf Science 51(1): 75-90.

Dissolved and particulate organic matter were studied in northern San Francisco Bay estuary on seven dates from April to October 1996 when flow from the Sacramento and San Joaquin river Delta was declining. Measurements were made at three to 11 stations (usually eight) along the salinity gradient from the Sacramento River to the Central Bay. Dissolved constituents included monosaccharides (MONO), total carbohydrates (TCHO), dissolved primary amines (DPA), dissolved organic carbon (DOC), and the fluorescence of humic substances (HF). Particulate constituents included bulk suspended particulate matter (SPM), chlorophyll a (CHL), particulate organic carbon (POC) and particulate organic nitrogen (PON). April was distinct from subsequent months due to very high DOC and MONO concentrations and somewhat elevated TCHO, DPA and HF concentrations. DOC, MONO, TCHO and HF concentrations generally decreased with increasing salinity suggesting an upper estuarine source of these constituents. In contrast, DPA had a bimodal distribution suggesting both upper and lower estuarine sources. There was evidence of a persistent, additional source of organic matter near Suisun Bay that was high in DOC and HF, but low in DPA. It was speculated that this material originated from one or more of the following: (a) the San Joaquin River, (b) exchange with the shoals and intertidal reaches of Suisun

Bay, and (c) flux of DOC from particulate organic matter (POM). The particulate organic constituents, POC and PON, strongly correlated with SPM but not with CHL, suggesting that sediments were relatively important and phytoplankton were relatively unimportant contributors to POM pools.

Myrick, C. A. and J. J. Cech (2004). "Temperature effects on juvenile anadromous salmonids in California's central valley: what don't we know?" Reviews in Fish Biology and Fisheries 14(1): 113-123.
        The anadromous Chinook salmon (Oncorhynchus tshawytscha) (4 runs) and steelhead (rainbow trout, O. mykiss), are both native to California's Sacramento-San Joaquin River (SSJR) system, whose watershed encompasses the central valley of California. The SSJR system holds the southernmost extant Chinook salmon populations in the Eastern Pacific Ocean, whereas coastal anadromous steelhead populations are found at more southerly latitudes. Populations of both species of anadromous salmonid have experienced dramatic declines during the past 100 years, at least partly from water impoundments and diversions on most central valley rivers and their tributaries. These changes restricted the longitudinal distribution of these salmonids, often forcing the superimposition of steelhead populations and Chinook salmon populations in the same reaches. This superimposition is problematic in part because the alterations to the river systems have not only changed the historic flow regimes, but have also changed the thermal regimes, resulting in thermally-coupled changes in fish development, growth, health, distribution, and survival. Given the highly regulated nature of the system, resource managers are constantly trying to strike a balance between maintaining or increasing the population size of anadromous fish runs and with other demands for the water, such as irrigation and water quality. To do so, in this review, we summarize the published information on the temperature tolerance and growth of the stream-associated life stages of these two valuable species, which are so central to the natural heritage of the State and its cultures. We show that many of these limits and growth-related effects are specific regarding life stage and that some may be specific to distinct strains or races of Chinook salmon and steelhead within the system. Because the number of published studies on the physiology of central valley salmonids was surprisingly low, we also use this review to highlight critical areas where further research is needed. Overall, this review should assist biologists and resource decision-makers with improved understanding for the protection and enhancement of these native fishes.

Nakamoto, R. J., and T.J. Hassler (1992). "Selenium and other trace elements in bluegills from agricultural return flows in the San Joaquin Valley, California." Archives of Environmental Contamination and Toxicology 22(1): 88-98.
        The effects of water quality and exposure to trace elements in irrigation return flows on bluegills (Lepomis macrochirus) were studied in the Merced River and Salt Slough, tributaries to the San Joaquin River, California, during 1988. Our study revealed that conductivity, turbidity, pH, total filterable residue, total hardness, and alkalinity were significantly greater in the Salt Slough, which receives tile drainage, then in the Merced River, which does not receive tile drainage. The concentrations of all trace elements, except aluminum and selenium, were below levels that are expected to have significant chronic toxic effects on bluegills. Selenium body burdens in bluegills from the Salt Slough have increased over fourfold since 1973. Age 1 bluegills from the Salt Slough were significantly shorter than age 1 bluegills from the Merced River. No other significant differences were noted in length by age. The mean length of age 1 bluegills from the Merced River has been increasing since 1983. In contrast, the length of age 1 bluegills from the Salt Slough has been decreasing. Fecundity of bluegills was lower in the Salt Slough than in the Merced River. The concurrent rise in selenium body burdens in bluegills from the Salt Slough and the decreasing total length of age 1 bluegills suggest a causal link between the two. In addition, the apparent depressed fecundity may also be related to the increased body burdens of selenium.

Nam, K. (2010). Concept of Potential Entrainment Index (PEI) and its applications for the Sacramento-San Joaquin Delta Management. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
        The Pelagic Organism Decline (POD) including the decline of delta smelt in

the Sacramento-San Joaquin Delta continues to be a major concern, and water exports from the Delta is suggested as one of the causes of the POD. Because of this, estimating the likely effect of water exports on Delta organisms is important for healthy Delta management, and the concept of the Potential Entrainment Index (PEI) is introduced as an indicator of the impact to the overall population of organisms in the Delta. The PEI, given a distribution of organisms throughout the Delta and hydrology within the Delta, estimates the overall potential percentage of particles entrained by the exports. The concept is tested for delta smelt larvae and juvenile fish in various Delta situations. Both DSM2-PTM simulations and regressions derived from simulation results are used to calculate PEIs, and studies show possibility of the PEI as an additional tool for the Delta management and fish protection. The PEI can be applied on a near real-time basis as soon as fish and relevant information is updated, and such a quick response is crucial for fish protection. There are limitations that can be significant in using this method including the uncertainty in the estimate of fish abundance provided in fish surveys and the assumption that the fish do not exhibit behavior. Thus, the PEI should be adopted carefully as an indicator, not a predicted actual entrainment, with the uncertainties, and more effort to reduce the uncertainties is necessary, e.g. obtaining higher quality of fish survey data, developing better numerical models, and understanding more of fish behaviors.

National Marine Fisheries Service (1997). "NMFS proposed recovery plan for the Sacramento River Winter-run chinook salmon."

Neilson, J. D., and C.E. Banford (1983). "Chinook salmon (Oncorhynchus tshawytscha) spawner characteristics in relation to redd physical features." Canadian Journal of Zoology 61(7): 1524-1531.
We studied the spatial pattern and physical characteristics of chinook salmon (Oncorhynchus tshawytscha) redds with respect to length of redd occupancy and when redd construction began. Spawners arriving first deposited their eggs in larger redds constructed in deeper, slower moving water. Redds constructed by late arriving fish were smaller on average and were usually located in relatively shallow, fast-flowing water. Late arriving fish also had a shorter average redd residence time. We suggest that progeny of early arriving spawners may have a selective advantage over progeny of late arriving fish in the same run.

Neilson, M. E. and R. R. Wilson (2005). "mtDNA singletons as evidence of a post-invasion genetic bottleneck in yellowfin goby Acanthogobius flavimanus from San Francisco Bay, California." Marine Ecology Progress Series 296: 197-208.
Yellowfin goby, a fish native to East Asia, was first reported in northern California (San Francisco Bay) in 1963 and in southern California (Los Angeles Harbor) in 1979. Over the past 4 decades, it has spread to other northern and southern California estuaries, respectively. The documented expansion of yellowfin goby in California provided an opportunity to study potential founder effects in a marine invasive fish by seeking evidence of reductions in mtDNA singleton haplotypes consistent with an expected loss of overall genetic diversity. We obtained samples of yellowfin goby from San Francisco Bay in northern California, from 2 small estuaries in southern California, and from Tokyo Bay, Japan, the presumed source population. The mtDNA control region was fully sequenced and analyzed for a total of 216 specimens, where the numbers of singleton haplotypes relative to the total number of haplotypes in each sample were compared to predictions from a regression analysis of singletons on total haplotypes. AMOVA comparisons among haplotype frequencies were also performed. Singleton haplotypes were significantly fewer than predicted among yellowfin goby of San Francisco Bay, indicating some loss of genetic diversity in that invasive population. Singletons were not significantly fewer than prediction among yellowfin goby of Tokyo Bay or of southern California. phi sub(ST) values were not significantly different between San Francisco and Tokyo bays, but were different between San Francisco Bay in northern California and southern California locations, suggesting separate introductions to California.

Neira, C., E. D. Grosholz, et al. (2006). "Mechanisms generating modification of benthos following tidal flat invasion by a Spartina hybrid." Ecological Applications 16(4): 1449-1460.

Many coastal habitats are being substantially altered by introduced plants. In San Francisco Bay, California, USA, a hybrid form of the eastern cordgrass Spartina alterniflora is rapidly invading open mudflats in southern and central sections of the Bay, altering habitat, reducing macrofaunal densities, and shifting species composition. The invasion has resulted in significant losses of surface-feeding amphipods, bivalves, and cirratulid polychaetes, while subsurface feeding groups such as tubificid oligochaetes and capitellid polychaetes have been unaffected. In the present paper, we document the causes and mechanisms underlying the changes observed. Through a series of in situ manipulative experiments we examined the influence of hybrid Spartina canopy on a range of physical, chemical, and biological properties. The hybrid Spartina canopy exerted a strong influence on the hydrodynamic regime, triggering a series of physical, chemical, and biological changes in the benthic system. Relative to tidal flats, water velocity was reduced in hybrid patches, promoting deposition of fine-grained, organic-rich particles. The resulting changes in the sediment environment included increased porewater sulfide concentrations and anoxia, which led to poor survivorship of surface feeders such as bivalves, amphipods, and polychaetes. These are key taxa that support higher trophic levels including migratory shorebirds that feed on tidal flats. Altered flow in the Spartina canopy further contributed to changes in barnacle recruitment and resuspension of adult benthic invertebrates. Increased crab-induced predation pressure associated with Spartina invasion also contributed to changes in benthic invertebrate communities. Our results suggest that multiple physical, chemical, biotic, and trophic impacts of the Spartina invasion have resulted in substantial changes in benthic communities that are likely to have important effects on the entire ecosystem.

Neira, C., L. A. Levin, et al. (2005). "Benthic macrofaunal communities of three sites in San Francisco Bay invaded by hybrid Spartina, with comparison to uninvaded habitats." Marine Ecology Progress Series 292: 111-126.
A hybrid cordgrass, formed from a cross between Spartina alterniflora (Atlantic cordgrass) and S. foliosa (Pacific cordgrass), has recently spread within the intertidal zone of south San Francisco Bay. Sediment properties and macroinfaunal community structure were compared in patches invaded by Spartina hybrid and adjacent uninvaded patches at 3 sites in San Francisco Bay (2 tidal flats and 1 Salicornia marsh). We hypothesized that (1) sediments vegetated by Spartina hybrid would have reduced sediment grain size, higher organic matter content, lower redox potential, lower salinity and reduced microalgal biomass relative to adjacent unvegetated tidal flat sediments, and (2) that differences in the sediment environment would correspond to changes in the infaunal invertebrate community structure and feeding modes. We observed 75% lower total macrofaunal density and lower species richness in Spartina-vegetated sediments at Elsie Roemer (30 yr old invasion) than in an adjacent unvegetated tidal flat. This was due to lower densities of surface-feeding amphipods, bivalves, cirratulid and spionid polychaetes. The proportional representation of subsurface-deposit feeders was greater in Spartina patches than in unvegetated sediments. At a more recently invaded site (Roberts Landing; 15 yr invasion), Spartina patches differed from tidal flat sediments in composition, but not in abundance. Native (Salicornia) and Spartina patches exhibited similar sediment properties at San Mateo, where the Spartina hybrid invaded 8 to 10 yr earlier. No differences were detected in densities or proportions of surface- or subsurface-deposit feeders, but the proportion of carnivores/omnivores and grazers increased in the hybrid-invaded patches. These studies suggest that the invasive Spartina hybrid in south San Francisco Bay can have differing effects on sediment ecosystems, possibly depending on the location, age, or type of habitats involved.

Nelson, C., G.M. Benigno, and L. Chu (2010). Pelagic macroinvertebrates of the Cache Slough Complex. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The Cache Slough Complex is considered important habitat for endangered native fish species such as delta smelt. Liberty Island, a main hydrologic feature of the area, was flooded in 1998 and has developed into a productive tidal freshwater wetland. The Cache Slough Complex is targeted as a priority for future tidal freshwater wetland habitat restoration. As part of a larger study effort to

understand the baseline hydrodynamics and food web resources of the area, pelagic macroinvertebrate samples were collected each season from summer 2008 through spring 2009. Here we report preliminary results describing the macroinvertebrate community of the Cache Slough Complex. The most abundant taxa collected, amphipods and mysids, have been previously identified as important components of fish diets in the delta. This finding provides further evidence of the importance of the Cache Slough Complex as fish habitat. Additionally, the baseline invertebrate community information will be a valuable reference dataset in the future to evaluate the success of future habitat restoration efforts.

Nelson, P., S. Kramer, N. Nur, and D. Zajanc (2010). Habitat-species associations and behavior of outmigrating juvenile steelhead (Oncorhynchus mykiss) and Chinook salmon (O. tshawytscha) in the lower Sacramento River, California. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Levee repair efforts on the lower Sacramento River (California) include mitigation measures intended to provide or improve habitat for juvenile salmonids. We identify habitat features and levee design types most conducive to successful rearing and residency of juvenile Chinook salmon (Oncorhynchus tshawytscha) and steelhead (Oncorhynchus mykiss), and least conducive to potential predators. Acoustic telemetry data on residency of tagged hatchery juveniles were obtained at 12 levee repair and 6 naturalized sites between RM 12.5 to 91.9, from late November 2008 to late April 2009. Fish assemblage data were collected by electrofishing 15 sites above RM 20. Analysis included the use of generalized linear models (GLM) and canonical correspondence analysis (CCA) to relate electrofishing catch and residency to levee repair designs and habitat variables (e.g., floodplain inundation ratio, bank slope, and instream woody material (IWM)). Residency was characterized as the likelihood of a fish staying at a site (>12 h), and for fish that did stay, their residency duration. Results from the GLM analyses showed that catch of 0+ juvenile Chinook salmon was positively related to floodplain inundation ratio and reduced bank slope. In addition, CCA showed a positive relationship between Chinook salmon and larval lamprey with increasing aquatic vegetation and quantity of IWM. In contrast to Chinook salmon, there were positive associations between catch of resident basses and bank slope, based on both GLM and CCA. For tagged 1+ steelhead, the probability of staying at a site was positively related to overhead shade and reduced bank slope. IWM diameter increased the probability of staying for tagged 1+ Chinook salmon. Residency duration for juvenile Chinook salmon and steelhead was positively associated with some measures of IWM. Our findings help explain habitat use and behavior of critical species in the Bay-Delta system, and can inform management strategies for habitat mitigation and conservation.

Nelson, S. M. and D. M. Lieberman (2002). "The influence of flow and other environmental factors on benthic invertebrates in the Sacramento River, U.S.A." Hydrobiologia 489(1-3): 117-129.

We examined how community composition of benthic invertebrates was related to current velocities and other environmental variables within the Sacramento River in California, USA. Invertebrates were collected in 1998 and 1999 from 10 sites over a gradient of 187 river kilometers. Canonical correspondence analysis revealed that current velocity was the most important variable explaining community composition. Other predicator variables that influenced community composition included periphyton biomass, altitude, and disturbance. Because of the importance of velocity in structuring benthic communities in this system, alterations of flow caused by changes in river regulation structures should be carefully considered.

Netto, J., and A. Aguilera (2010). The effect of tidal stage on fish abundance in near shore habitat. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

How fish use the habitat available to them can have an impact on the effectiveness of management actions, such as fish protection measures and habitat restoration. For this analysis we used of existing monitoring data to determine if tidal stage influences the abundance and composition of the fish community in the near shore habitat in the lower delta. The Delta Juvenile Fish Monitoring Program (DJFMP) has sampled with beach seines for the past 30 years to monitor juvenile

fishes throughout the Sacramento-San Joaquin River Delta. We generated estimates of tidal stage for the past beach seine sampling events in the lower delta from this data set, and evaluated the fish catches as a function of tidal stage. We found a strong tidal effect on catches of many fish including delta smelt, longfin smelt, and chinook salmon. Overall, beach seine catches during ebb tides were higher than catches during flood tides. The strength and nature of the tidal influence varied by species as do the potential mechanisms describing the patterns. This analysis provides insight into the use of habitat by fish in the delta through the integration and evaluation of existing data. Fully understanding the behavior of fish will take more focused effort and specific hypotheses than this analysis, but the review of existing data can provide immediate information and help frame future research efforts.

Newman, K. B. (2003). "Modelling paired release-recovery data in the presence of survival and capture heterogeneity with application to marked juvenile salmon." Ecological Modelling 3(3): 157-177.
Products of multinomial models have been the standard approach to analysing animal release-recovery data. Two alternatives, a pseudo-likelihood model and a Bayesian nonlinear hierarchical model, are developed. Both approaches can to some degree account for heterogeneity in survival and capture probabilities over and above that accounted for by covariates. The pseudo-likelihood approach allows for recovery period specific overdispersion. The hierarchical approach treats survival and capture rates as a sum of fixed and random effects. The standard and alternative approaches were applied to a set of paired release-recovery salmon data. Marked juvenile chinook salmon (Oncorhynchus tshawytscha) were released, with some recovered in freshwater as juveniles and others in marine waters as adults. Interest centered on modelling freshwater survival rates as a function of biological and hydrological covariates. Under the product multinomial formulation, most covariates were statistically significant. In contrast, under the pseudo-likelihood and hierarchical formulations, the standard errors for the coefficients were considerably larger, with pseudo-likelihood standard errors five to eight times larger, and fewer coefficients were statistically significant. Covariates, significant under all formulations, with important management implications included water temperature, water flow and amount of water exported for human use. The hierarchical model was considerably more stable with regard to estimated coefficients of training subsets used in a cross-validation.

Newman, K. B. (2008). "Sample design-based methodology for estimating delta smelt abundance." San Francisco Estuary and Watershed Science 6(3).
A sample design-based procedure for estimating pre-adult and adult delta smelt abundance is described. Using data from midwater trawl surveys taken during the months of September, October, November, and December for the years 1990 through 2006 and estimates of size selectivity of the gear from a covered codend experiment, stratified random sample ratio estimates of delta smelt abundance were made per month. The estimation procedure is arguably an improvement over the dimensionless delta smelt indices that have been used historically in that (1) the volume sampled is used in a manner that leads to directly interpretable numbers and (2) standard errors are easily calculated. The estimates are quite imprecise, i.e., coefficients of variation in the range of 100% occurred. The point estimates are highly correlated with the monthly indices, and conclusions on abundance declines are quite similar. However, both the estimates and indices may suffer from selection biases if the trawl samples are not representative of the true densities. Future work is needed in at least three areas: (1) gathering additional information to determine the validity of assumptions made, in particular determining the possible degree of selection bias; (2) developing procedures that utilize survey data gathered from earlier life history stages, such as larval surveys; (3) embedding a life-history model into the population estimation procedure.

Newman, K. B. and P. L. Brandes (2010). "Hierarchical Modeling of Juvenile Chinook Salmon Survival as a Function of Sacramento-San Joaquin Delta Water Exports." North American Journal of Fisheries Management 30(1): 157-169.

Newman, K. B. and S. T. Lindley (2006). "Accounting for demographic and

environmental stochasticity, observation error, and parameter uncertainty in fish population dynamics models." North American Journal of Fisheries Management 26: 685-701.
Bayesian hierarchical state-space models are a means of modeling fish population dynamics
while accounting for both demographic and environmental stochasticity, observation noise, and parameter
uncertainty. Sequential importance sampling can be used to generate posterior distributions for parameters,
unobserved states, and random effects for population models with realistic dynamics and error distributions.
Such a state-space model was fit to the Sacramento River winter-run Chinook salmon Oncorhynchus
tshawytscha population, where a key objective was to develop a tool for predicting juvenile out-migration
based on multiple sources of data. One-year-ahead 90% prediction intervals based on 1992 2003 data, while
relatively wide, did include the estimated values for 2004. Parameter estimates for the juvenile production
function based on the state-space model formulation differed appreciably from Bayesian estimates that
ignored autocorrelation and observation noise.

Newman, K. B. and J. Rice (2002). "Modeling the survival of chinook salmon smolts outmigrating through the lower Sacramento River system." Journal of the American Statistical Association 97: 983-993.
To study the factors associated with the freshwater mortality of outmigrating chinook salmon, releases of tagged juvenile salmon were made at multiple locations in the Sacramento River each spring between the years 1979 and 1995. A midwater trawl located downstream of the release sites caught salmon soon after release and, 1 to 4 years later, samples taken from the catches of marine fisheries recovered other tagged fish. An extended quasi-likelihood model was fit to both the freshwater and the marine recoveries. A ridge parameter was included to stabilize the parameter estimates and to improve predictive ability. Overdispersion was due, at least in part, to heterogeneity in the trawl's capture efficiency, as well as to the complex aggregation of marine recoveries. Different dispersion parameters were used for the river and ocean recoveries because of the additional sources of variation experienced by ocean recoveries relative to river recoveries. Interpretation of estimated coefficients was delicate, given the correlation between some of the covariates, the biases introduced by the ridge parameter, and possible confounding factors. With these caveats in mind, we found the most influential covariate to be the temperature of the water into which the fish were released, with increasing temperarures having a negative association with recoveries. Three covariates were of particular interest to the biologists and water managers: water flow, position of a water diversion gate (open or closed) separating the mainstem from the central delta, and relative fraction-of water exported for irrigation and urban consumption. The effects of flow were slightly positive but were confounded by salinity levels. The effect of the water diversion gate being open was to, lower apparent survival for fish released above the gate, but apparent survival increased for fish released in the central delta into which the water was diverted. There was evidence that increasing the export-to-inflow ratio lowered survival, but the effect was slight and not statistically significant.

Ngatia, M., B. Templin, D. Guy, C. Garcia, B. Agee, K. Pepper, S. Fong, P. Lebeouf, K. Gehrts et. al. (2012). "Quality Assurance & Quality Control for DWR Data." California Department of Water Resources, 20th Annual Environmental Scientist Workshop. from
http://www.water.ca.gov/environmentalservices/docs/qaqc/120917__Ngatia_Templin_Guy__etal__ES_Conf_2012_QAQC_Poster_Final.pdf.
The Division of Environmental Services has established a QA Workgroup. The Mission of the QA Workgroup is to increase awareness of quality assurance and quality control for all of the Department's water-related data. WREM 60 established policy and procedures to assure that quality assurance is used in the Department's

chemical, ahd physical measurements, data collection, and data measurement and management activities. QA Workgroup goals include sharing existing QA plans and developing procedures for QA Plan review and approval.

Nichol, G. D. (1996). Estuarine circulation cell of lower Sacramento River, University of Nevada, Reno.

Nichols, F. H. (1979). Natural and anthropogenic influences on benthic community structure in San Francisco Bay. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 409-426.

Nichols, F. H. (1985). "Abundance fluctuations among benthic invertebrates in two Pacific estuaries." Estuaries 8: 136-144.

Long-tern studies were used to examine (1) contrasting time scales and mechanisms of structural variations within two benthic communities and (2) the usefulness of long data sets for evaluating human impact. A 10-year study of a San Francisco Bay mudflat, the details of which are reported elsewhere, has revealed large short-term variations in species abundances within a community composed predominantly of opportunistic species. Only a very long-term data set may provide evidence of progressive change. Data collected for a 20-year period on the benthic community at 200 m depth in the main basin of Puget Sound, show that numerical abundance of the common species can also change markedly. Here, however, numerical dominance shifts from one species to another at irregular, multiyear intervals. A significant increase in total numbers of individuals suggest that long-term changes may be occurring in this community.

Nichols, F. H. (1985). "Increased benthic grazing: an alternative explanation for low phytoplankton biomass in northern San Francisco Bay during the 1976-1977 drought." Estuarine, Coastal and Shelf Science 21: 379-388.

Among the consequences of extremely low river flow into northern San Francisco Bay during a two-year drought were (1) a gradual increase in salinity, (2) an unusual decline in chlorophyll a concentration, and (3) the upstream migration of estuarine benthic invertebrates to the normally brackish area of the bay. Total abundance in the benthos at a shallow monitoring site increased from a normal 2000 to greater than 20000 individuals m super(-2) during the summer of 1977, presumably in response to the increased salinity. Estimated filtration rates derived from equations in the literature for one of the species, the suspended-feeding bivalve Mya arenaria ranged from 1 to 4 m super(3) m super(-2) day super(-1) during 1977 depending on abundance and mean size on sampling dates. Because water depth at this site is less than 2 m, Mya could have filtered all of the particles (including diatoms) from the water column on the order of once per day.

Nichols, F. H., and J.K. Thompson (1985). "Time scales of change in the San Francisco Bay benthos." Hydrobiologia 129(1): 121-138.

Results from multi-year investigations in the San Francisco Bay estuary show that large abundance fluctuations within benthic macroinvertebrate populations reflect both (1) within-year periodicity of reproduction, recruitment, and mortality that is not necessarily coincident with seasonal changes of the environment (e.g., the annual temperature cycle), and (2) aperiodic density changes (often larger than within-year fluctuations) following random perturbations of the environment. Density peaks of the small, short-lived estuarine invertebrates that comprise the vast majority of individuals in the bay's relatively homogeneous benthic community normally occur between spring and autumn depending on the species, in large part a reflection of reproductive periodicity. However, because mild winters permit reproductive activity in some of the common species throughout much of the year, other factors are important to within-year density fluctuations in the community. Seasonally predictable changes in freshwater inflow, wind and tidal mixing, microalgal biomass, and sediment erosion/deposition patterns all contribute to observed seasonal changes in abundance. For example, the commonly observed decline in abundance during winter reflects both short-lived species that die after reproducing and the stress of winter conditions (e.g., inundation by less saline, sediment-laden water and the decline in both planktonic and benthic algal biomass –

a direct source of food for the shallow-water benthos). On the other hand, data from several studies suggest that observed recruitment and mortality may in fact be the migration of juveniles and adults to and from study sites. For example, the common amphipod Ampelisca abdita apparently moves from shallow to deep water, or from up-estuary to down-estuary locations, coincident with periods of high river runoff in winter. Growth of individuals within the few studied species populations is also highly seasonal, and appears to be coincident with seasonal increases in the abundance of planktonic and/or benthic microalgae. Two multi-year studies have shown that, in addition to within-year periodicity, major restructuring of the benthic community can occur as a result of anomalous (usually climate-related) perturbations of the benthic habitat. For example, during wet years freshwater-intolerant species disappear from the upper part of the estuary and from shallow areas of the bay. During a two-year drought these same species colonized the extreme upper end of the estuary in large numbers. Other aperiodic perturbations include localized instances of sediment erosion or deposition and algal mat accumulations that greatly depress abundance. Additionally, there is evidence (observations that the clam Macoma balthica establishes large populations only when the amphipod A. abdita is not abundant) that species interactions can contribute greatly to interannual variations. Thus, while community composition may change little over the long term, year-to-year predictability of species abundances is low.

Nichols, F. H., J.E. Cloern, S.N. Luoma, and D.H. Peterson (1986). "The modification of an estuary." Science 231: 567-573.

The San Francisco Bay estuary has been rapidly modified by human activity. Diking and filling of most of its wetlands have eliminated habitats for fish and waterfowl; the introduction of exotic species has transformed the composition of its aquatic communities; reduction of freshwater inflow by more than half has changed the dynamics of its plant and animal communities; and wastes have contaminated its sediments and organisms. Continued disposal of toxic wastes, the probable further reduction in freshwater inflow, and the possible synergy between the two provide the potential for further alteration of the estuary's water quality and biotic communities.

Nichols, F. H., J.K. Thompson, and L.E. Schemel (1990). "Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam Potamocorbula amurensis. 2. Displacement of a former community." Marine Ecology Progress Series 66(1-2): 95-101.

Long-term macrobenthic sampling at a site in northern San Francisco Bay has provided an unusual opportunity for documenting the time course of an invasion by a recently introduced Asian clam Potamocorbula amurensis . Between 1977, when sampling began, and 1986, when the new clam was first discovered, the benthic community varied predictably in response to river inflow. During years of normal or high river inflow, the community consisted of a few brackish or freshwater species. During prolonged periods of low river inflow, the number of species doubled as estuarine species (e.g. Mya arenaria) migrated up the estuary. In June 1987, at the beginning of the longest dry period in recent decades, large numbers (> 12,000 m super(-2)) of juvenile P. amurensis were discovered at the site. By mid-summer 1988 the new clam predominated (> 95%) in both total number of individuals and biomass, and the expected dry-period estuarine species did not become re-established.

Nichols, F. H. and M. M. Pamatmat (1988). The ecology of the soft-bottom benthos of San Francisco Bay: a community profile, U.S. Fish and Wildlife Service, Biological Report 85(7.19).

Nichols, F. H. and J. K. Thompson (1982). "Seasonal growth in the bivalve Macoma balthica near the sourthern limit of its range." Estuaries 5: 110-120.

Shell-length growth in Macoma balthica from San Francisco Bay, California, as measured on living animals in situ , is highly seasonal despite a mild Mediterranean climate: a long period of near non-growth from May to the following February is followed by a short period of rapid growth between March and May. The rapid-growth period follows the spawning period during January/February and ends as water temperature rises above about 15 degree C. Despite the shortness of the growth period, M. balthica grows larger at a given age in San Francisco Bay than is recorded elsewhere in the world. Application of a model, developed elsewhere from these same field measurements, shows that (1) measurable growth occurs during the summer/autumn/early winter "nongrowth" period, (2) there is an autumn recruitment, and (3) both spring and autumn recruits combine to form a single "one-year-old" size grouping.

Nichols, F. H. and J. K. Thompson (1985). "Persistence of an introduced mudflat community in south San Francisco Bay, California." Marine Ecology Progress Series 24: 83-97.

The benthic invertebrate community inhabiting the extensive and sedimentologically homogeneous mudflats of South San Francisco Bay has demonstrated a high degree of constancy in both species composition and relative abundance among species throughout 10 yr of observation. The community, composed predominantly of introduced species with opportunistic lifestyles, is dominated numerically by Gemma gemma, Ampelisca abdita , and Streblospio benedicti . The key to the persistent co-occurrence of these species on the nudflats seems to lie in the combination of (1) the recurrence of minor disturbances of the mudflat habitat (e.g. sediment deposition/erosion, inundation by low-salinity water) on time scales comparable to that of life cycles; (2) opportunistic life history strategies (rapid maturity, brooding of young, multiple generations each year, ease of local dispersal of both juveniles and adults) that permit continued colonization of the mudflat surface or rapid recolonization after disturbances.

Nichols, K. (2010). They’re dying, but are they sick? 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The possible role of disease, impaired physiological development and xenobiotic exposure were examined as a contributor to the low egg-to-smolt survival of juvenile Stanislaus River Chinook Salmon during out-migration. Fish were sampled at the Oakdale (upper) and Caswell (lower) rotary screw trap sites during March, April and May, 2010. A standard pathology suite (bacteriology, virology and parasitology), energy reserves, and smolt development were analyzed at the CA-NV Fish Health Center laboratory. No biologically significant problems have been detected in the assays completed by the time of this writing. If disease or physiological problems are identified as contributing to low out-migrant survival on the Stanislaus River, improved survival may be possible through management actions.

Nicholson, D., S. Dyhrman, et al. (2006). "Alkaline phosphatase activity in the phytoplankton communities of Monterey Bay and San Francisco Bay." Limnology and Oceanography 51(2): 874-883.

Enzyme-labeled fluorescence (ELF) and bulk alkaline phosphatase (AP) activity enzyme assays were used to evaluate the phosphorus (P) status of phytoplankton communities in San Francisco and Monterey bays. Both regions exhibit spatial and temporal variability in bulk AP activity with maximum activities during the early spring and summer periods of high biological productivity. ELF analysis revealed pronounced differences in the makeup of organisms responsible for AP activity in these two environments. In Monterey Bay dinoflagellates are responsible for the bulk of the AP activity. Diatoms infrequently exhibited AP activity. Dinoflagellates that comprised only 14% of all cells counted in Monterey Bay accounted for 78% of AP-producing cells examined. The presence of AP activity in this group suggests that changes in P sources, concentrations, and bioavailability could disproportionably influence this group relative to diatoms in Monterey Bay. In San Francisco Bay, AP production, indicated by ELF, was associated primarily with bacteria attached to suspended particles, potentially used to hydrolyze organic compounds for carbon, rather than to satisfy P requirements. Our results highlight the importance of organic P as a bioavailable nutrient source in marine ecosystems and as a component of the marine P cycle.

Nicolini, M. H. and D. L. Penry (2000). "Spawning, Fertilization, and Larval Development of Potamocorbula amurensis (Mollusca: Bivalvia) from San Francisco Bay, California." Pacific Science 54(4): 377-388.

In Potamocorbula amurensis time for development to the straight-hinge larval stage is 48 hr at 15 degree C. Potamocorbula amurensis settles at a shell length of approximately 135 mu m 17 to 19 days after fertilization. Our observations of timing

of larval development in P. amurensis support the hypothesis of earlier workers that its route of initial introduction to San Francisco Bay was as veliger larvae transported in ballast water by trans-Pacific cargo ships. The length of the larval period of P. amurensis relative to water mass residence times in San Francisco Bay suggests that it is sufficient to allow substantial dispersal from North Bay to South Bay populations in concordance with previous observations that genetic differentiation among populations of P. amurensis in San Francisco Bay is low. Potamocorbula amurensis is markedly euryhaline at all stages of development. Spawning and fertilization can occur at salinities from 5 to 25 psu, and eggs and sperm can each tolerate at least a 10-psu step increase or decrease in salinity. Embyros that are 2 hr old can tolerate salinities from 10 to 30 psu, and by the time they are 24 hr old they can tolerate the same range of salinities (2 to 30 psu) that adult clams can. The ability of P. amurensis larvae to tolerate substantial step changes in salinity suggests a strong potential to survive incomplete oceanic exchanges of ballast water and subsequent discharge into receiving waters across a broad range of salinities.

Nielsen, J. L., S. A. Pavey, et al. (2005). "Genetics of Central Valley O. mykiss populations: drainage and watershed scale analyses." San Francisco Estuary and Watershed Science 3(2): [np].
Genetic variation at 11 microsatellite loci described population genetic structure for Oncorhynchus mykiss in the Central Valley, California. Spatial and temporal variation was examined as well as relationships between hatchery and putative natural spawning anadromous stocks. Genetic diversity was analyzed at two distinct spatial scales: fine-scale within drainage for five populations on Clear Creek; between and among drainage diversity for 23 populations. Significant regional spatial structure was apparent, both within Clear Creek and among rainbow trout populations throughout the Central Valley. Significant differences in allelic frequencies were found among most river or drainage systems. Less than 1% of the molecular variance could be attributed to differences found between drainages. Hatchery populations were shown to carry similar genetic diversity to geographically proximate wild populations. Central Valley M = 0.626 (below the M < 0.68 threshold) supported recent population reductions within the Central Valley. However, average estimated effective population size was relatively high (Ne = 5066). Significant allelic differences were found in rainbow trout collected above and below impassable dams on the American, Yuba, Stanislaus and Tuolumne rivers. Rainbow trout sampled in Spring Creek were extremely bottlenecked with allelic variation at only two loci and an estimated effective population size of 62, suggesting some local freshwater O. mykiss stocks may be declining rapidly. These data support significant genetic population structure for steelhead and rainbow trout populations within the Central Valley across multiple scales. Careful consideration of this genetic diversity and its distribution across the landscape should be part of future conservation and restoration efforts.

Nielson, J. L., D. Tupper, and W.K. Thomas (1994). "Mitochondrial DNA polymorphism in unique runs of chinook salmon (Oncorhynchus tshawytscha) from the Sacramento-San Joaquin river basin." Conservation Biology: the journal of the Society for Conservation Biology 8(3): 882-884.
Electrophoretic data from California fish have been unable to provide within-basin resolution of genotypes at the temporal spawning-run level in the Central Valley chinook populations. In an effort to gain such resolution, we examined mtDNA polymorphisms in fish collected from the Sacramento-San Joaquin River Basin. Mitochondrial DNA was extracted from 312 samples of fin tissue taken from 7 populations of Central Valley chinook. Six chinook mtDNA types were identified by sequencing a highly variable segment of the maternally inherited mitochondrial molecule. Chinook in the Sacramento-San Joaquin Basin have historically been separated into four temporial runs based on the seasonal distribution of their peak spawning times: fall run (October-December), late fall run (January-April), winter run (April-August) and spring run (August-October). The purpose of this study was to check for unique molecular genetic markers...

Nielson, J. L., T.E. Lisle, and V. Ozaki (1994). "Thermally stratified pools and their use by steelhead in northern California streams." Transactions of the American

Fisheries Society 123(4): 613-626.
Thermal stratification occurred in pools of three rivers in northern California when inflow of cold water was sufficiently great or currents were sufficiently weak to prevent thorough mixing of water of contrasting temperatures. Surface water temperatures in such pools were commonly 3–9°C higher than those at the bottom. Cold water entered pools from tributaries, intergravel flow through river bars, and streamside subsurface sources. In Redwood and Rancheria Creeks, cold water was protected where gravel bars encroached into pools that were scoured along bedrock banks, creating isolated backwaters. Sixty-five percent of the juvenile steelhead Oncorhynchus mykiss found in the Rancheria Creek study reaches moved into adjacent stratified pools during periods of high ambient stream temperatures (23–28°C). Fish showed a decline in forage behavior and increased agonistic activity just before movement into stratified pools. In the Middle Fork Eel River, pools deeper than 3 m stratified when surface flow decreased to less than 1 m3/s. Summer-run steelhead adults were found in deep stratified pools on the Middle Fork Eel River throughout summer when midday ambient stream temperatures ranged from 26 to 29°C and coldwater pockets averaged 3.5°C cooler. Thermally stratified pools provided refuge habitat for significant numbers of young-of-the-year, yearling, and adult steelhead in marginal river habitats where stream temperatures reach upper incipient lethal levels.

Nilsen, E. B. and M. L. Delaney (2005). "Factors Influencing the Biogeochemistry of Sedimentary Carbon and Phosphorus in the Sacramento-San Joaquin Delta." Estuaries 28(5): 653-663.
This study characterizes organic carbon (C sub(organic)) and phosphorus (P) geochemistry in surface sediments of the Sacramento-San Joaquin Delta, California. Sediment cores were collected from five sites on a sample transect from the edge of the San Francisco Bay eastward to the freshwater Consumnes River. The top 8 cm of each core were analyzed (in 1-cm intervals) for C sub(organic), four P fractions, and redox-sensitive trace metals (uranium and manganese). Sedimentary C sub(organic) concentrations and C sub(organic) : P ratios decreased, while reactive P concentrations increased moving inland in the Delta. The fraction of total P represented by organic P increased inland, while that of authigenic P was higher bayward than inland reflecting increased diagenetic alteration of organic matter toward the bayward end of the transect. The redox indicator metals are consistent with decreasing sedimentary suboxia inland. The distribution of P fractions and C : P ratios reflect the presence of relatively labile organic matter in upstream surface sediments. Sediment C and P geochemistry is influenced by site-specific particulate organic matter sources, the sorptive power of the sedimentary material present, physical forcing, and early diagenetic transformations presumably driven by C sub(organic) oxidation.

Ning, X., J.E. Cloern, and B.E. Cole (2000). "Spatial and temporal variability of picocyanobacteria Synechococcus sp. in San Francisco Bay, (USA)." Limnology and Oceanography 45(3): 695-702.
We collected samples monthly, from April to August 1998, to measure the abundance of autotrophic picoplankton in San Francisco Bay. Samples taken along a 160-km transect showed that picocyanobacteria (Synechococcus sp.) was a persistent component of the San Francisco Bay phytoplankton in all the estuarine habitats, from freshwater to seawater and during all months of the spring-summer transition. Abundance ranged from 4.6 × 106 to 5.2 × 108 cells L-1, with peak abundance during the spring bloom (April and May) and during July with a persistent spatial pattern of smallest abundance near the coastal ocean and highest abundance in the landward domains of the estuary. The picocyanobacterial component (as estimated percentage of chlorophyll a concentration) was, on average, 15% of total phytoplankton biomass during the summer-autumn nonbloom periods and only 2% of chlorophyll biomass during the spring bloom. This result is consistent with the emerging concept of a gradient of increasing importance of picocyanobacteria along the gradient of decreasing nutrient concentrations from estuaries to the open ocean.

Noble, B. (2009). 2008 Dissolved Oxygen Monitoring in the Stockton Ship Channel. iEP Newsletter. 22: 6.

Noble, B., and Brown, T. (2010). Dissolved oxygen monitoring in the Stockton Ship Channel for 2008 and 2009. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The Department of Water Resources (DWR) Bay-Delta Monitoring and Analysis Section has been monitoring dissolved oxygen (DO) levels in the Stockton Ship Channel during the late summer and fall since 1968. Due to a variety of factors, DO levels have historically fallen in the central and eastern portions of the channel during this period. Some of the factors responsible include low San Joaquin River inflows, warm water temperatures, high biochemical oxygen demand (BOD), reduced tidal circulation, and intermittent reverse flow in the San Joaquin River at Stockton. Because low DO levels can have adverse impacts on fisheries and other beneficial uses of the waters within the Bay-Delta, the State Water Resources Control Board (SWRCB) established specific water quality objectives to protect these uses. This poster describes DO monitoring results, and the phytoplankton community in the Stockton turning basin, for the years 2008 and 2009. DO levels varied by season and between regions within the channel, with some areas showing stratification with depth, and occasionally falling below the established objectives. The phytoplankton community varied greatly during the sampling period, with different types of phytoplankton dominating at different times. Monitoring DO levels in the Stockton Ship Channel is essential for assuring that SWRCB DO objectives are met, and to protect the beneficial uses of water in the Delta.

Noble, B. (2010). Water Quality Monitoring. Water Quality Conditions in the Sacramento-San Joaquin Delta and Suisun and San Pablo Bays during 2008, Report to the State Water Resources Control Board in Accordance with Water Rights Decision 1641. D. Riordan. West Sacramento, CA, California Department of Water Resources: 3-1 to 3-41.

Nobriga, M. L. (1998). Evidence of food limitation in larval delta smelt. IEP Newsletter. 11: 20-24.

Nobriga, M. L., T. Veldhuizen, and Z. Hymanson (1999). Delta smelt concerns result in changes in SWP and CVP operations. IEP Newsletter. 12: 33-34.

Nobriga, M. L., Z. Hymanson, and R. Oltmann (2000). Environmental factors influencing the distribution and salvage of young delta smelt: a comparison of factors occurring in 1996 and 1999. IEP Newsletter. 13: 55-65.

Nobriga, M. L., and M. Chotkowski (2000). Recent historical evidence of centrarchid increases and tule perch decrease in the Delta. IEP Newsletter. 13: 23-27.

Nobriga, M. L., and P. Cadrett (2001). Differences among hatchery and wild steelhead: evidence from Delta fish monitoring programs. IEP Newsletter 14: 30-38.

Nobriga, M. L., Z. Hymanson, K. Fleming, and C. Ruhl (2001). Spring 2000 delta smelt salvage and Delta hydrodynamics and an introduction to the Delta Smelt Working Group's Decision Tree. IEP Newsletter. 14: 42-46.

Nobriga, M. L. (2002). "Larval delta smelt diet composition and feeding incidence: environmental and ontogenetic influences." California Fish and Game 88: 149-164.
I examined the feeding ecology of larval delta smelt, Hypomesus transpacificus, a threatened fish endemic to the upper San Francisco Estuary (SFE). The larvae were collected during the California Department of Fish and Game ichthyoplankton surveys during spring 1992-1994. The study objectives were (1) compare current diet composition to limited historical data; (2) describe seasonal and ontogenetic influences on diet; and (3) determine whether feeding success varied interannually, and if so, in association with what factors. In most months, historically important prey, (cyclopid copepods and the calanoid copepod Eurytemora affinis) dominated the diet. The calanoid copepod Pseudodiaptomus forbesi, introduced to the SFE in 1987, was an important prey in late spring. Electivity analysis indicated use of the aforementioned copepods was related to their abundance, but changes in the abundance of other zooplankton were not reflected in the diet. Ontogenetic changes in the size of prey ingested were apparent; the

smallest feeding larvae ate mostly subadult copepods, whereas larvae > 13 mm ate mostly adult copepods. Feeding incidence (FI), the presence or absence of food in the gut, increased with larval length, but for certain length groups varied up to 30% among years. A Separate Slopes Analysis of Covariance (ANCOVA) indicated larval length was positively correlated with Principal Components scores representing a gradient in calanoid copepod abundance. The ANCOVA also demonstrated that on average, feeding larvae were collected in association with higher calanoid copepod abundance than equivalently sized non-feeding larvae. Overall these results suggest (1) larval delta smelt are primarily dependent on three prey taxa, two of which have undergone a long-term decline in abundance and (2) larval delta smelt feeding success is related to prey abundance. I conclude that well-documented ecological changes in the SFE have probably been detrimental to larval delta smelt, but that linking long-term or interannual food web variability to recruitment will require further research.

Nobriga, M. L., M. Chotkowski, and R. Baxter (2003). Baby steps toward a conceptual model of predation in the delta: preliminary results from the Shallow Water Habitat Predator-Prey Dynamics Study. IEP Newsletter. 16: 19-27.

Nobriga, M. L., Z. Matica, and Z.P Hymanson (2004). Evaluating entrainment vulnerability to agricultural irrigation diversions: A comparison among open-water fishes. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi. Bethesda, Maryland, American Fisheries Society. Symposium 39: 281-295.

In July 2000 and 2001, we sampled adjacent screened and unscreened agricultural irrigation diversions in the Sacramento River, California to (1) evaluate the effectiveness of a custom fish screen for excluding four open-water fishes: native delta smelt Hypomesus transpacificus and alien threadfin shad Dorosoma petenense, inland silverside Menidia beryllina, and striped bass Morone saxatilis; and (2) examine factors affecting entrainment of each species. We also compiled trawl and beach seine data from contemporaneous monitoring programs to make inferences about microhabitat use by these fishes and its implications for entrainment vulnerability. The fish screen reduced entrainment of each species by 99% or more and excluded many fish less than 25 mm, the approximate minimum length it was designed to exclude. Tidal and diel influences on entrainment through the unscreened diversion were observed, but diel cycles appeared to be more important, as most entrainment occurred at night or during crepuscular periods. Except for delta smelt, our results suggested that open-water fishes may undergo ontogenetic changes in vulnerability to unscreened irrigation diversions. Fishes entrained during daylight (threadfin shad and striped bass) averaged only 15–16 mm in length. At night, average lengths of entrained threadfin shad and inland silverside were 22–25 mm, even though larvae continued to be entrained. Similarly, a diel influence on striped bass entrainment was observed only in 2000, when individuals larger than 20 mm were consistently collected. No striped bass were collected at sizes greater than 35 mm, even though larger individuals occupied the study area. We found no evidence of size-related changes in delta smelt vulnerability to entrainment, but the monitoring data indicated that delta smelt were abundant offshore, whereas the other three species were most abundant nearshore. We think that low and inconsistent entrainment of delta smelt reflected (1) predominantly offshore habitat use by delta smelt, and (2) the relatively small hydrodynamic influence of the diversion.

Nobriga, M. L., F. Feyrer, R. Baxter, and M. Chotkowski (2005). "Fish community ecology in an Altered River delta: Spatial patterns in species composition, life history strategies, and biomass " Estuaries and Coasts 28 (5): 776-785.

We sampled nearshore fishes in the Sacramento-San Joaquin Delta, California, United States, during 2001 and 2003 with beach seines and gill nets. We addressed three questions. How and why did fish assemblages vary, and what local habitat features best explained the variation? Did spatial variation in assemblages reflect greater success of particular life history strategies? Did fish biomass vary among years or, across habitats? Nonmetric multidimensional scaling showed that habitat variables had more influence on fish assemblages than temporal variables. Results from both gear types indicated fish assemblages varied between Sacramento and San Joaquin River sampling sites. Results from gill net sampling were less pronounced than those from beach seine sampling. The Sacramento and San Joaquin river sites differed most notably in terms of water clarity and abundance of submerged aquatic vegetation (SAV), suggesting a link between these habitat characteristics and fish relative abundance. Among-site differences in the relative abundance of periodic and equilibrium strategist species suggested a gradient in the importance of abiotic versus biotic community structuring mechanisms. Fish biomass varied among years, but was generally higher in SAV-dominated habitats than the turbid, open habitats in which we found highest abundances of striped bass Morone saxatilis and special-status native fishes such as delta smelt Hypomesus transpacificus, Chinook salmon Oncorhyncus tschawytscha, and splittail Pogonichthys macrolepidotus. The low abundance of special-status fishes in the comparatively productive SAV-dominated habitats suggests these species would benefit more from large-scale restoration actions that result in abiotic variability that mirrors natural river-estuary habitat than from actions that emphasize local (site-specific) productivity.

Nobriga, M. L., F. Feyrer, and R. Baxter (2006). "Aspects of Sacramento pikeminnow biology in nearshore habitats of the Sacramento-San Joaquin Delta, California." Western North American Naturalist 66(1): 106-114.

We documented distribution, relative abundance, diet composition, and body condition of Sacramento pikeminnow Ptychocheilus grandis during 2001 and 2003 at 5 sites in the Sacramento–San Joaquin Delta, California. Sacramento pikeminnow densities in nearshore habitats were higher in 2003 than 2001. In both years, spatial distribution of beach seine densities was similar. There were no significant differences in density among sampling sites except for the southernmost site where the catch was near zero. Based on rotary screw-trap data from a 6th site, we found relative abundance of Sacramento pikeminnow entering the Delta via an artificial floodplain was positively correlated with flow. Most individuals collected using all 3 gear types were age 1 or older, and appeared to grow quickly based on data from previous studies. Sacramento pikeminnow had diverse diets composed of freshwater and estuarine invertebrate and fish taxa. Incidence of piscivory was only 2% of the diet of individuals <150 mm, but increased to 50% for fish over 150 mm. No salmonids were observed in foregut contents during the study. In both years body condition declined abruptly in July. Our results suggest Sacramento pikeminnow are more common in the turbid, tidal freshwater habitats of the Delta than was previously recognized. Stream flows may play an important role in moving juvenile Sacramento pikeminnow into the Delta from upstream areas. Similar to northern pikeminnow P. oregonensis, but in seeming contrast to endangered Colorado pikeminnow P. lucius, the present study showed that Sacramento pikeminnow can be successful in altered habitats.

Nobriga, M. L., and F. Feyrer (2007). "Shallow-water piscivore-prey dynamics in California’s Sacramento-San Joaquin Delta." San Francisco Estuary and Watershed Science 5(2): Article 4.

Predation is one mechanism that could lead to low native fish abundance in macrophyte dominated shallow-water habitats in the Sacramento-San Joaquin Delta. We used beach seine and gill net sampling to identify and compare the distribution and feeding ecology of three piscivores (striped bass, Morone saxatilis, largemouth bass, Micropterus salmoides, and Sacramento pikeminnow, Ptychocheilus grandis) at five nearshore sites in the Sacramento-San Joaquin Delta. Sampling was conducted March-October 2001 and 2003. We addressed the following questions. What are the spatial and temporal distributions of age-1 and older striped bass, largemouth bass, and Sacramento pikeminnow? What prey are eaten by these predators? What is the relative importance of predator size versus seasonal prey availability on incidence of piscivory for these predators? What is the likely per capita impact of each piscivore on prey fishes, particularly native fishes? All 76 of our individual station visits yielded at least one of the three species, suggesting that piscivorous fishes frequently occur in Delta shallow-water habitats. All three piscivores had diverse diets.There were noticeable seasonal shifts in prey fish for each of the three piscivores. In general, most native fish were consumed during spring (March-May) and the highest prey species richness occurred during summer (June-August). Largemouth bass likely have the highest per capita impact on nearshore fishes, including native fishes. Largemouth bass preyed on a greater diversity of native fishes than the other two piscivores and consumed native fishes farther into the season (July versus May). Based on binomial generalized additive

models, incidence of piscivory was predominantly a function of size for largemouth bass and Sacramento pikeminnow. Largemouth bass became predominantly piscivorous at smaller sizes than Sacramento pikeminnow; about 115 mm versus about 190 mm respectively. In contrast, incidence of piscivory was predominantly a function of season for striped bass. Striped bass were typically most piscivorous during summer and fall regardless of size. We conclude that shallow-water piscivores are widespread in the Delta and generally respond in a density-dependent manner to seasonal changes in prey availability.

Nobriga, M. L., and Frederick Feyrer (2008). "Diet composition in San Francisco Estuary striped bass: does trophic adaptability have its limits? ." Environmental Biology of Fishes 83(4): 495-503.

Trophic adaptability is a term used to describe feeding flexibility in fishes. Though a useful conceptual starting point, fishes often face constraints on their ability to switch prey that could limit feeding success even when prey switching is observed. We compared striped bass diet compositions summarized from previously published studies in California’s Sacramento-San Joaquin Delta during two time periods (1963–1964 and 2001–2003), which allowed us to evaluate trophic adaptability in San Francisco Estuary striped bass at multiple time scales, ranging from intra-annual to multidecadal. The Delta is the landward region of the San Francisco Estuary; over time between the study periods, the Delta underwent substantial changes in potential prey availability for striped bass. We found evidence for trophic adaptability in San Francisco Estuary (SFE) striped bass at all temporal scales examined. Despite this ability to adapt to changes in prey availability, the relative abundance and carrying capacity of young striped bass have declined. This decline has previously been associated with substantial declines in their dominant historical prey—mysid shrimp. Our results, coupled with these previous findings, indicate that trophic adaptability may have limited usefulness as a conceptual model to predict foraging success when other food web constraints are not considered. We speculate that this is particularly true in highly invaded ecosystems like the San Francisco Estuary because invading species often introduce substantial and permanent changes into food webs, decreasing the likelihood that a predator will find prey assemblages that fully replace historical prey assemblages.

Nobriga, M. L. (2009). "Bioenergetic modeling evidence for a context-dependent role of food limitation in California’s Sacramento-San Joaquin Delta." California Fish and Game 95(3): 111-127.

Nobriga, M. L., and E. Loboschefsky (2010). Modeling the needle in the haystack: Striped bass piscivory on delta smelt. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The top-down influence of predators like striped bass (Morone saxatilis) on prey fishes is one of the least understood aspects of the Bay-Delta food web. This is particularly true for rare fishes that rarely show up in examinations of striped bass stomach contents. We used regression techniques to summarize a large amount of bioenergetics modeling and diet composition data for Bay-Delta striped bass. This provided a statistical tool that predicts both diet composition and consumption of age-1 through age-6 striped bass. We used this tool to explore a hypothetical predator-prey dynamic between striped bass and delta smelt. To do this, we had to make a key assumption that the available functional response data for striped bass feeding on Mississippi silverside (Menidia audens), approximate the functional response to the endangered delta smelt (Hypomesus transpacificus) because of the morphological similarity of these two fishes. The bioenergetic model predicts striped bass consumption increases rapidly as functions of striped bass length and water temperature. However, this is counteracted by the functional response; striped bass eat fewer small prey fishes as they grow larger. Thus, our analysis suggests that age-1 and age-2 striped bass (i.e., juveniles) are the largest contributors to delta smelt consumption. However, even under the conditions modeled, which represented summer water temperatures and comparatively high densities of delta smelt in the water column, the model predicted the median fraction of juvenile striped bass eating delta smelt was about 1 in 10,000, and that ≤ 1 in 1,000,000 adult striped bass would eat delta smelt on any given summer day. This is consistent with delta smelt’s lack of occurrence in recent striped bass diet

studies and their very low occurrence in historical studies done when delta smelt were more common, but still rare compared to other striped bass prey.

Nobriga, M. L., T. R. Sommer, et al. (2008). "Long-Term Trends in Summertime Habitat Suitability for Delta Smelt (Hypomesus transpacificus)." San Francisco Estuary and Watershed Science 6(1): 13.

The biological productivity of river-dominated estuaries is affected strongly by variation in freshwater inflow, which affects nursery habitat quality. Previous research has shown this is generally true in the upper San Francisco Estuary, California, USA; however, one endemic species of high management importance, delta smelt (Hypomesus transpacificus), has shown ambiguous population responses to river inflow variation. We hypothesized that population-level associations with abiotic habitat metrics have not been apparent because the effects occur seasonally, and at spatial scales smaller than the entire upper San Francisco Estuary. We tested this hypothesis by applying regression techniques and principal components analysis (PCA) to a long-term data-set (1970–2004) of summertime fish catch, and concurrently measured water quality (specific conductance, Secchi disk depth, and water temperature). We found that all three water quality variables predicted delta smelt occurrence, and we identified three distinct geographic regions that had similar long-term trends in delta smelt capture probabilities. The primary habitat region was centered on the confluence of the Sacramento and San Joaquin rivers; delta smelt relative abundance was typically highest in the Confluence region throughout the study period. There were two marginal habitat regions—including one centered on Suisun Bay—where specific conductance was highest and delta smelt relative abundance varied with specific conductance. The second marginal habitat region was centered on the San Joaquin River and southern Sacramento-San Joaquin Delta. The San Joaquin region had the warmest water temperatures and the highest water clarity, which increased strongly in this region during 1970–2004. In the San Joaquin region, where delta smelt relative abundance was correlated with water clarity, catches declined rapidly to zero from 1970–1978 and remained consistently near zero thereafter. However, when we combined these regional results into estuary-wide means, there were no significant relationships between any of the water quality variables and delta smelt relative abundance. Our findings support the hypothesis that basic water quality parameters are predictors of delta smelt relative abundance, but only at regional spatial scales.

Null, S., J. Viers, J. Mount, M. Deas, and S. Tanaka (2010). River temperature impacts and resiliency to climate warming in California’s Sierra Nevada. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

This study assesses climate warming impacts on stream temperatures in west-slope Sierra Nevada watersheds from the Feather River to the Kern River. Weekly instream flow estimates from WEAP21, a spatially explicitly, one-dimensional, rainfall-runoff model were passed to RTEMP, an equilibrium water temperature model, to estimate river temperatures using the heat budget, coarse river channel geometry, and exposure time of water to atmospheric conditions. Air temperature was uniformly increased by 2ºC, 4ºC, and 6ºC as a sensitivity analysis to bracket the range of likely outcomes for regional stream temperatures. Other meteorological conditions, including precipitation, were left unchanged from historical values. Model results were analyzed to highlight water temperature resiliency, including contributing factors such as elevation, latitude, baseflow, drainage area, and stream order. Overall, water temperatures increase most at middle elevations (1,500 – 2,500 m), where snowfall is expected to shift to rainfall, and rivers may heat by more than 1.5ºC for each 2ºC increase in air temperature. River temperatures are generally most resilient to climate warming at the high elevations of southern Sierra Nevada watersheds. Future changes to river temperatures are likely to impact instream habitat conditions, altering the distribution and abundance of fish and wildlife. This work improves our understanding of water temperature resiliency to climate warming for rivers in the Sierra Nevada, and provides river temperature estimates for water managers who must balance instream habitat protection with human water uses, such as water supply, hydropower, flood control, and recreation. Future research includes assessing water temperature resiliency with regulated conditions and climate warming because cold-water supplies from large reservoirs may increase

opportunities to manage water temperature in Sierra Nevada rivers.

O’Rear, T. A. (2010). Trends in fishes and invertebrates of Suisun Marsh. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Obrebski, S., J. J. Orsi, et al. (1992). "Long Term Trends in Zooplankton Distribution and Abundance in the Sacramento-San Joaquin Estuary. Interagency Ecological Study for the Sacramento-San Joaquin Estuary, Technical Report 32. 42pp."

Odom, D., and D.E. Portz (2010). Developing underwater video technology for sampling pelagic delta fishes. “SmeltCam II”. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

O'Farrell, M. R. and R. J. Larson (2005). "Year-class formation in Pacific herring (Clupea pallasi) estimated from spawning-date distributions of juveniles in San Francisco Bay, California." Fishery Bulletin 103(1): 130-141.
Inter and intra-annual variation in year-class strength was analyzed for San Francisco Bay Pacific herring (Clupea pallasi) by using otoliths of juveniles. Juvenile herring were collected from March through June in 1999 and 2000 and otoliths from subsamples of these collections were aged by daily otolith increment analysis. The composition of the year classes in 1999 and 2000 were determined by back-calculating the birth date distribution for surviving juvenile herring. In 2000, 729% more juveniles were captured than in 1999, even though an estimated 12% fewer eggs were spawned in 2000. Spawning-date distributions show that survival for the 2000 year class was exceptionally good for a short (approximately 1 month) period of spawning, resulting in a large abundance of juvenile recruits. Analysis of age at size shows that growth rate increased significantly as the spawning season progressed both in 1999 and 2000. However, only in 2000 were the bulk of surviving juveniles a product of the fast growth period. In the two years examined, year-class strength was not predicted by the estimated number of eggs spawned, but rather appeared to depend on survival of eggs or larvae (or both) through the juvenile stage. Fast growth through the larval stage may have little effect on year-class strength if mortality during the egg stage is high and few larvae are available.

Officer, C. B., T. J. Smayda, et al. (1982). "Benthic filter feeding: a natural eutrophication control." Marine Ecology Progress Series 9: 203-310.
The importance of the benthic filter feeding community as a natural control on eutrophication is considered. The important environmental factors favorable for such a control are relatively shallow water depths and a dense benthic filter feeding community of small animals. The criteria are summarized in the equivalence of the water recycling time, tau sub(f') for the benthic community and the time consant, tau sub(p') for phytoplankton growth. The criteria are applied specifically to the conditions that exist in South San Francisco bay.

Ohlendorf, H. M. (2002). "The birds of Kesterson Reservoir: a historical perspective." Aquatic Toxicology 57(1-2): 1-10.
Beginning in the late 1970s, Kesterson Reservoir was used for disposal of subsurface drainage from agricultural fields in California's San Joaquin Valley. During 1983-1985, studies were conducted to evaluate the effects of chemicals in this agricultural drainwater on aquatic birds using Kesterson Reservoir. These studies included analyses of food-chain biota (such as plants, aquatic invertebrates, and fish) and bird tissues or eggs, as well as measuring adverse effects on health and reproduction of the birds. Results of the integrated set of field and experimental studies showed that selenium was the only chemical found at concentrations high enough to cause the adverse effects on bird health or reproduction that were observed. This article provides a summary of the field studies conducted at Kesterson Reservoir (and some of the related field and experimental studies conducted elsewhere) to evaluate the effects of irrigation drainage water contaminants on aquatic birds. (C) 2002 Elsevier Science B.V. All rights reserved.

Ohlendorf, H. M. and W. R. Gala (2000). "Selenium and Chevron Richmond Refinery's water enhancement wetland: A response to A.D. Lemly, 1999." Human and ecological risk assessment 6(5): 903-905.

Ohlendorf, H. M., R. L. Hothem, et al. (1990). "BIOACCUMULATION OF SELENIUM IN BIRDS AT KESTERSON RESERVOIR, CALIFORNIA." Archives of Environmental Contamination and Toxicology 19(4): 495-507.

Ohlendorf, H. M., R. L. Hothem, et al. (1989). "NEST SUCCESS, CAUSE-SPECIFIC NEST FAILURE, AND HATCHABILITY OF AQUATIC BIRDS AT SELENIUM-CONTAMINATED KESTERSON RESERVOIR AND A REFERENCE SITE." Condor 91(4): 787-796.

Ohlendorf, H. M., R. W. Lowe, et al. (1986). "SELENIUM AND HEAVY-METALS IN SAN-FRANCISCO BAY DIVING DUCKS." Journal of Wildlife Management 50(1): 64-70.

Ohlendorf, H. M. and K. C. Marois (1990). "ORGANOCHLORINES AND SELENIUM IN CALIFORNIA NIGHT-HERON AND EGRET EGGS." Environmental Monitoring and Assessment 15(1): 91-104.

Ohlendorf, H. M., K. C. Marois, et al. (1991). "TRACE-ELEMENTS AND ORGANOCHLORINES IN SURF SCOTERS FROM SAN-FRANCISCO BAY, 1985." Environmental Monitoring and Assessment 18(2): 105-122.

Surf scoters (Melanitta perspicillata) were collected from 6 locations in San Francisco Bay during January and March 1985. Overall, mean concentrations of cadmium and zinc were higher in livers of scoters from the southern region of the Bay, whereas mean iron and lead were higher in those from the northern Bay region. Mean concentrations of arsenic, copper, lead, zinc, aluminum (January only) and iron (January) also differed among individual locations. Mean concentrations of copper and zinc increased, arsenic decreased, and cadmium remained the same between January and March. Selenium and mercury concentrations in scoter livers were not significantly correlated ($P > 0.05$), but cadmium concentrations in livers and kidneys were positively correlated ($P < 0.0001$), and body weight was negatively related to mercury concentration in the liver ($P < 0.05$). Body weight differed among locations but not between January and March. Body weight was correlated with lipid content ($P < 0.0001$). DDE and PCBs were each detected in 34 of 36 scoter carcasses. DDE increased significantly between January and March at Richmond Harbor, but BCBs did not differ between January and March at the 3 locations that could be tested.

Okamoto, A. R., and K.M. Wong (2011). Natural History of San Francisco Bay, University of California Press.

This complete primer on San Francisco Bay is a multifaceted exploration of an extraordinary, and remarkably resilient, body of water. Bustling with oil tankers, laced with pollutants, and crowded with forty-six cities, the bay is still home to healthy eelgrass beds, young Dungeness crabs and sharks, and millions of waterbirds. Written in an entertaining style for a wide audience, Natural History of San Francisco Bay delves into an array of topics including fish and wildlife, ocean and climate cycles, endangered and invasive species, and the path from industrialization to environmental restoration. More than sixty scientists, activists, and resource managers share their views and describe their work—tracing mercury through the aquatic ecosystem, finding ways to convert salt ponds back to tidal wetlands, anticipating the repercussions of climate change, and more. Fully illustrated and packed with stories, quotes, and facts, the guide also tells how San Francisco Bay sparked an environmental movement that now reaches across the country.

Olsen, K. L., P.J. Hrodey, and S.M. Bollens (2010). Assemblage and diet of native and non-native nearshore fishes in a restoring wetland in the northern Sacramento-San Joaquin Delta, California. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The loss and degradation of natural habitat contributes considerably to the decline of native estuarine fish species. We focused our research within Liberty Island, California, a restoring tidal wetland, where we examined how native and non-native nearshore fish assemblages varied seasonally and interannually in relation to hydrography. In addition, we investigated fish diet composition, overlap and potential resource competition among native and non-native species. Nearshore fishes were collected by beach seine on a weekly basis between August 2002 and October 2004 as part of a USFWS CALFED-funded monitoring effort. The fish community composition between 2002 and 2004 comprised 32 taxa, with less than half (13) identified as native to the Sacramento-San Joaquin Delta. Species abundance was influenced by two interacting factors: physiological tolerances and the timing and place of reproduction of the abundant species. This was further confirmed when nonmetric multidimensional scaling indicated that seasonality and water temperature exhibited the greatest influence on fish assemblages. Notably, Delta smelt were caught year-round at Liberty Island and although numbers remained relatively low (between zero and 23 fish 1000m-3) compared to more common species, abundances were greater than in other areas of the Delta. Additional fish were collected by beach seine for diet analysis in June 2007 and June 2008 as a follow-up study; inland silverside, yellowfin goby and Sacramento splittail, accounted for 94% of the total catch. Key diet items for inland silversides were insects, crustaceans and copepods, whereas splittail consumed more diverse prey items, but consisted mainly of detritus. Insects were the largest portion of stomach content for yellowfin goby, which also consumed ostracods and eggs. Similarity of percentages analysis of these three species indicated that there was very little diet similarity. Finally, non-native and native fishes utilize Liberty Island year-round and in particular during spawning, thus this tidal marsh habitat is important. Future studies should focus on determining what habitat/physiochemical features of the island make it attractive to native species (especially Delta smelt).

Olsen, K. L., S. Bayer, D. Gewant, and C. Wepking (2010). Nekton response in Breach III: Evaluating and predicting ‘restoration thresholds’ in evolving freshwater-tidal marshes. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The Sacramento-San Joaquin Delta (Delta) of the San Francisco Estuary (SFE) is a highly manipulated ecosystem with structural impacts including levees and water diversions that have occurred over the last century. But many restoration efforts are underway, including at Liberty Island, a breached levee island once used for agriculture that is thought to provide good habitat for fish, particularly species of concern (i.e. Delta smelt and Chinook salmon). We are examining the nekton response to the restoring tidal wetlands of Liberty Island as part of a larger, multi-disciplinary, multi-institutional effort called “Breach III” (see other posters and talks in this special session). We have begun intensively sampling the nekton at six sites on Liberty Island during three main periods of differing environmental conditions: wet, transitional, and dry conditions. More specifically, we are investigating the relationship between fish assemblages, life histories and diet in un-vegetated and vegetated habitats across the colonization threshold. During our first intensive sampling period (March 27 – April 2, 2010) we caught 12 species using gill nets, fyke nets and purse seines in a variety of landscape settings and across various vegetation thresholds. The most abundant species caught were the non-native inland silversides; seven of the species captured were identified as non-native. Notably, six Delta smelt were caught, which is a federally listed endangered species. Preliminary results indicate that in vegetated habitat, inland silversides and Delta smelt consumed similar prey items, which consisted mainly of chironomids, Corophium sp. and calanoid copepods. Further results of diet analyses of the dominant fish species during March/April will be presented. We will also present preliminary results on composition and diet of fishes at Liberty Island from our scheduled sampling in August 2010, a dry period. These results will be discussed in relation to other previous and ongoing restoration projects in the Delta and SFE.

Oltmann, R. N. (1998). Measured flow and tracer-dye data showing anthropogenic effects on the hydrodynamics of south Sacramento-San Joaquin delta, California, Spring 1996 and 1997, USGS Open-File Report 98-285.

O'Rear, T. A., and P.B. Moyle (2010). Long Term and Recent Trends of Fishes and Invertebrates in Suisun Marsh. IEP Newsletter. 23: 24.

Suisun Marsh, at the geographic center of the San Francisco Estuary, is important habitat for alien and native fishes. The University of California, Davis,

Suisun Marsh Fish Study has systematically monitored the marsh's fish populations since 1980. The purpose of the study has been to determine the environmental factors affecting fish abundance and distribution, especially in relation to water management activities. Otter trawl catches of native fishes declined considerably from the study's beginning until about 1995; since then, it has stabilized somewhat at relatively low levels. Although the trend was less severe, otter trawl catches of alien fishes also declined until the early 1990s. Since the study's inception, otter trawl catch of alien fishes has been highly variable, primarily due to erratic recruitment and invasions of new species. Beach seine catch has gradually increased over the study's history, which has been mainly the result of rising Mississippi silverside (Menidia audens) numbers. Both 2008 and 2009 were dry years, although Delta outflows remained higher and more variable later in 2009. In 2008, 286 otter trawls, 19 midwater trawls, and 76 beach seine hauls were conducted. Fish per otter trawl was the second lowest recorded in the study's history, which was partially due to the negative effects of salinity and lack of flooding on reproduction. However, many fishes that declined in otter trawls [e.g., yellowfin goby (Acanthogobius flavimanus), shimofuri goby (Tridentiger bifasciatus),striped bass (Morone saxatilis)] became much more abundant in beach seines. Additionally, only 14 individual fish were captured in midwater trawls, catches of 4 plankton-feeding macroinvertebrates declined in otter trawls, and the abundance of mysids was very low. In 2009, 256 otter trawls and 75 beach seines were conducted. Relative to 2008, fish per otter trawl increased while beach seine catches declined, mainly due to the fishes that most strongly contributed to the catches in 2008: striped bass and yellowfin and shimofuri gobies. This was partially due to favorable outflows spanning the recruitment period of these fishes into the marsh. Similar to the otter trawl catch of fish, catch trends of 3 of the 4 macroinvertebrates increased from 2008 to 2009, and large mysid catches co-occurred with high catches of small fishes. Consequently, catches of 2008 and 2009 appeared to be largely determined by the magnitude, variability,
and timing of Delta outflows and the abundance of pelagic food supplies.

O'Riordan, C. A., S. G. Monismith, et al. (1993). "A study of concentration boundary-layer formation over a bed of model bivalves." Limnology and Oceanography 38(8): 1712-1729.

We conducted experiments in a laboratory flume to study the interaction of bivalve siphonal currents with the turbulent boundary layer, using a bed of model Tapes japonica (625 animals m super(-2)). Refiltration of excurrent fluid, which represents a decrease in aggregate feeding efficiency, was measured for 225 siphon pairs oriented perpendicular to the cross-flow (free stream flow) direction. Refiltration was as high as 18% and related to position in the bed, pumping rate, and siphon height of the animals, as well as the cross-flow speed. Scaling analysis of refiltration data suggests that the velocity ratio, VR = u sub(j)/u sub(*), where u sub(j) is the jet velocity and u sub(*) is the boundary shear velocity of the cross flow, is a good predictor of refiltration for VR > 20. Laser-induced fluorescence was used to visualize the flow. Analysis of the height of maximum phytoplankton depletion and spreading width of the plume obtained from quantitative concentration profiles show that changes in the vertical momentum of the excurrent jet become more important in determining the phytoplankton removal efficiency as VR decreases. The hydrodynamics of this complex interaction suggest that changes in pumping rate and siphon height will improve phytoplankton removal efficiency only for animals feeding in a strong cross flow.

O'Riordan, C. A., S. G. Monismith, et al. (1995). "The effect of bivalve excurrent jet dynamics on mass transfer in a benthic boundary layer." Limnology and Oceanography 40(2): 330-344.

Predictions of phytoplankton depletion by benthic bivalves in shallow, tidally driven estuaries must account for the formation of concentration boundary layers resulting from the dynamic interaction of bivalve siphonal currents with the overlying turbulent boundary layer. To study the near-bed hydrodynamics of the benthic boundary layer, we conducted experiments in a laboratory flume using multiple jets and sinks to represent feeding by the siphonate species Tapes japonica and Potamocorbula amurensis. Refiltration fractions were determined by monitoring the concentration of dye ingested by incurrent siphons, and PLIF (planar laser-induced fluorescence) was used to characterize the concentration fields. Results show that refiltration fractions can be as high as 48% and are a function of several dimensionless parameters: animal spacing (S/d sub(o)), velocity ratio (u sub(j) : u sub(*)), siphon height (h sub(s)/d sub(o)), and crossflow Reynolds number (Re sub(x)). (S is the mean distance between animals, d sub(o) the excurrent siphon diameter, h the animal siphon height, u sub(j) the excurrent jet velocity, and u sub(*) the mean shear velocity.) We found that a good estimate of maximum refiltration (n sub(max)) based on animal spacing is (n sub(max)S/d sub(o)) approximately 2-3 and have incorporated this result into a conceptual mass-transfer model. Differences in concentration profiles calculated from PLIF images are likely due to the relative influence of four sources of turbulence in the flow: boundary-layer shear, boundary roughness, jet in a crossflow, and multiple jet interactions.

Oros, D. R., D. Hoover, et al. (2005). "Levels and Distribution of Polybrominated Diphenyl Ethers in Water, Surface Sediments, and Bivalves from the San Francisco Estuary." Environmental Science & Technology 39(1): 33-41.

Polybrominated diphenyl ethers (PBDEs) were found in water, surface sediments, and bivalve samples that were collected from the San Francisco Estuary in 2002. capital sigma PBDE concentrations in water samples ranged from 3 to 513 pg/L, with the highest concentrations found in the Lower South Bay (range 103-513 pg/L) region, which receives approximately 26% of the Estuary's wastewater treatment plant effluents. The capital sigma PBDEs in sediments ranged from below detection limits to 212 ng/g dry wt, with the highest concentration found at a South Bay station (212 ng/g dry wt), which was up to 3 orders of magnitude higher than other stations. The capital sigma PBDE concentrations ranged from 9 to 64 ng/g dry wt in oysters (Crassostrea gigas), from 13 to 47 ng/g dry wt in mussels (Mytilus califonianus), and from 85 to 106 ng/g dry wt in clams (Corbicula fluminea). Only three PBDE congeners were detected in bivalves, BDE-47, BDE-99, and BDE-100; these are the most bioaccumulative congeners from the commercial Penta-BDE mixture.

Oros, D. R., W. M. Jarman, et al. (2003). "Surveillance for previously unmonitored organic contaminants in the San Francisco Estuary." Marine Pollution Bulletin 46(9): 1102-1110.

The San Francisco Estuary Regional Monitoring Program initiated surveillance monitoring to identify previously unmonitored synthetic organic contaminants in the San Francisco Estuary. Organic extracts of water samples were analyzed using gas chromatography-mass spectrometry in full scan mode. The major contaminant classes identified in the samples were fire retardants, pesticides, personal care product ingredients, and plasticizers. Evidence from the literature suggests that some of these contaminants can persist in the environment, induce toxicity, and accumulate in marine biota and in higher food chain consumers. The major sources of these contaminants into the marine environment are the discharge of municipal and industrial wastewater effluents, urban stormwater, and agricultural runoff. As a proactive effort, it is suggested that surveillance studies be used routinely in monitoring programs to identify and prevent potential problem contaminants from harming the marine environment.

Oros, D. R. and J. R. Ross (2004). "Polycyclic aromatic hydrocarbons in San Francisco Estuary sediments." Marine Chemistry 86(3-4): 169-184.

The objectives of this study were to examine surface sediments in the San Francisco Estuary for PAH composition over a range of spatial and temporal scales to determine distributions, trends, and possible sources. Surface sediments (top 5 cm) were collected at 26 sites from 1993 to 2001. The mean total PAH (PAH) concentration in sediments was spatially distributed as Central Bay (230 mg/kg TOC), South Bay (217 mg/kg TOC), North Estuary (96 mg/kg TOC), Extreme South Bay (87 mg/kg TOC), and Delta (31 mg/kg TOC). Overall, the mean PAH concentrations were significantly higher in the Central Bay and South Bay segments compared to the North Estuary, Extreme South Bay and Delta segments, and the Delta was significantly lower than all other segments (Kruskal-Wallis, H=156.94, df=4, p=0.000). In addition, no significant difference in PAH concentration was found between the Central Bay and South Bay. This distribution reflects the large amount of urbanized and industrialized areas that surround the Central Bay and South Bay compared to the less urbanized and rural areas surrounding the Delta. Temporal trend analysis showed a statistically significant temporal trend in PAH concentration at only 1 of the 26 sampling sites located throughout the estuary (San Pablo Bay, significant decrease, p=0.024, r super(2)=0.314, n=16), which suggests that PAH concentrations in the estuary generally remained constant from 1993 to 2001. Source analysis using PAH isomer pair ratios as indicators showed that PAH are derived primarily from combustion of fossil fuels/petroleum (gasoline, crude oil, and coal) and biomass (wood and grasses), with minor amounts of PAH derived from direct petroleum input.

Oros, D. R. and J. R. M. Ross (2005). "Polycyclic aromatic hydrocarbons in bivalves from the San Francisco estuary: Spatial distributions, temporal trends, and sources (1993-2001)." Marine Environmental Research 60(4): 466-488.
Bivalve tissue samples were examined over a range of spatial and temporal scales (1993-2001) to determine PAH distributions, trends, and possible sources. Mussels (Mytilus californianus), oysters (Crassostrea gigas), and clams (Corbicula fluminea) were deployed for three months in the estuary at stations remote from known point source discharges. The range of Sigma PAH detected in bivalves was oysters 184-6899 mu g/kg dry wt (mean 678 mu g/kg dry wt), mussels 21-1093 mu g/kg dry wt (mean 175 mu g/kg dry wt), and clams 78-720 mu g/kg dry wt (mean 323 mu g/kg dry wt). Linear regression analysis showed no statistically significant (P > 0.05) temporal trends in clam and mussel Sigma PAH at any of the deployment stations or estuary segments. On the other hand, a statistically significant (p < 0.05) decreasing trend was found in Sigma PAH in oysters at the Petaluma River station, and in the North Estuary segment. PAH isomer pair ratios applied as diagnostic indicators suggested that the bioaccumulated PAH were derived primarily from petroleum combustion, with lesser amounts derived from biomass and coal combustion, and unburned petroleum. (c) 2005 Elsevier Ltd. All rights reserved.

Oros, D. R., J. R. M. Ross, et al. (2007). "Polycyclic aromatic hydrocarbon (PAH) contamination in San Francisco Bay: A 10-year retrospective of monitoring in an urbanized estuary." Environmental Research 105(1): 101-118.
Polycyclic aromatic hydrocarbons (PAH) are widespread contaminants in the San Francisco Bay. Several exceedances of water quality criteria raise the possibility that PAH may be impacting aquatic biota. The Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) has collected annual monitoring data on PAH in the Bay since 1993. Analysis of Bay water, sediment, and mussel capital sigma PAH concentration data showed that there were very few significant (P<0.05) increasing or decreasing temporal trends in capital sigma PAH concentrations in the Bay during the period of 1993-2001. Wet and dry season input of PAH did not show any major influence on water capital sigma PAH concentrations over the same period. Based on their relative contribution to the estimated total maximum PAH loading (10,700kg/yr) into the Bay, the PAH loading pathways are ranked as storm water runoff (~51%)>tributary inflow (~28%)>wastewater treatment plant effluent (~10%)>atmospheric deposition (proportional to %)>dredged material disposal (arrow up %). The PAH sediment quality threshold of 1000ng/g, which has been previously suggested by NOAA to protect estuarine fish such as English sole against adverse health effects, was frequently exceeded at individual monitoring stations (11 of the 26 stations exceeded the threshold over 50% of the time). Modeling results have shown that the predominant loss pathway for PAH is degradation in sediments, and unless external loading levels of PAH are controlled, the Bay is not expected to recover rapidly.

Orr, M., N. Garrity, P. Quickert, J. Chamberlin, J. Melby, J. Cain, B. Herbold, C.A. Simenstad, N. Hershey, and G. Platenkamp (2010). Implementing at the project scale to inform science-based regional wetland restoration: the Dutch Slough Tidal Marsh Restoration in the Sacramento-San Joaquin Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The 1,170-acre Dutch Slough Tidal Marsh Restoration Project is seen as a significant step in recovery of the ecological health of the Sacramento-San Joaquin Delta, particularly for recovery of Bay-Delta fishes. It is the largest restoration designed to recreate the freshwater tidal marshplain and channels characteristic of the historic Delta. It’s also an important learning opportunity. The project

partners worked with an interdisciplinary group of scientists to integrate adaptive management experiments with restoration. What we learn from these experiments is intended to inform regional restoration design and implementation. The Dutch Slough restoration will include large-scale experiments to test the relationship of tidal marshplain elevation and marsh size/scale to the growth and survival of juvenile salmon and splittail. The plan will also include smaller-scale experiments related to wetland production of methyl mercury and dissolved organic carbon, and tidal channel formation. During planning, project partners and scientists grappled with the following questions: • Which parameters are both most uncertain and most important to test? Which are most likely to affect ecosystem benefits and management decisions related to cost and selection of future restoration sites? • How important is experimental replication? How many experiments can we realistically include? • Which parameters require testing at a large scale? Which can be tested on a smaller scale? • How do we balance trade-offs between learning and restoration? The Dutch Slough project is being planned by the California Department of Water Resources, California State Coastal Conservancy, Reclamation District 2137, and American Rivers with funding from the California Bay-Delta Authority.

Orr, M., S. Crooks, et al. (2003). "Will restored tidal marshes be sustainable?" San Francisco Estuary and Watershed Science 1: 5.

Orsi, J. J. (1971). "The 1965-1967 migrations of the Sacramento-San Joaquin estuary striped bass population." California Fish and Game 57: 257-267.

Orsi, J. J., and A.C. Knutson. (1979). The role of mysid shrimp in the Sacramento-San Joaquin Estuary and factors affecting their abundance and distribution. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, American Association for the Advancement of Science, Pacific Division: 401-408.

Six species of mysid shrimp are present in the Sacramento-San Joaquin Estuary, but only one of them, Neomysis mercedis, is abundant here. It is an important fish food in Suisun Bay and the Delta, especially for young-of-the-year striped bass. N. mercedis feeds on phytoplankton, detritus, and zooplankton. Its distribution is apparently determined by estuarine circulation acting on its vertical migration pattern. These factors concentrate it in the zone where fresh and salt water initially mix. Light intensity greater than 10-5 lux on the bottom and net flow velocity <0.12 m·s-1 apparently limit its upstream spread. In the San Joaquin River low populations are associated with low dissolved oxygen concentrations in combination with high temperatures. Fecundity appears to be a function of female length, temperature, and food supply (phytoplankton). Seasonal fluctuations in reproduction are usually paralleled by population fluctuations. Population differences between years appear to be a function of food supply and habitat size.

Orsi, J. J., T.E. Bowman, D.C. Marelli, and A. Hutchinson. (1983). "Recent introduction of the planktonic calanoid copepod Sinocalanus doerrii (Centropagidae) from mainland China to the Sacramento-San Joaquin Estuary of California." Journal of Plankton Research 5(3): 357-375.

The planktonic calanoid copepod, Sinocalanus doerrii, a native of the rivers of mainland China was found in 1978 in California's Sacramento-San Joaquin Estuary during routine plankton sampling. Previous plankton surveys in 1963 and from 1972 to the present indicate that the introduction occurred a relativery short time before specimens were first caught. The most probable mode of introduction is ballast water from Japanese freighters previously docking in China. S. doerrii became abundant in the Sacramento and San Joaquin Rivers in 1979 and may be regarded as well established. Its impact on the native plankton is as yet unknown.

Orsi, J. J. (1986). "Interaction between diel vertical migration of a mysidacean shrimp and two-layered estuarine flow." Hydrobiologia 137: 79-87.

Neomysis mercedis (Holmes) has a diel vertical migration pattern that interacts with two-layered estuarine flow and a turbid entrapment zone to keep the population from being swept out of the upper Sacramento-San Joaquin Estuary. In the entrapment zone mysids are found near surface on all night tides but are present at

that level during day only on flood tides. In the clearer water downstream from the entrapment zone mysids are not found near surface during day. In both locations a higher percentage of juveniles than adults are near surface. Individuals swept downstream from the entrapment zone in the seaward moving surface layer are apparently transported back upstream via the bottom density current. Thus, the population circulates both vertically and longitudinally but there is no net seaward movement except in response to changes in location of the entrapment zone. Due to their greater near surface abundance on flood tides which move them upstream, neonates are less abundant than adults seaward of the entrapment zone.

Orsi, J. J., and W.L. Mecum. (1986). "Zooplankton distribution and abundance in the Sacramento-San Joaquin Delta in relation to certain environmental factors." Estuaries and Coasts 9(4B): 326-339.

The dominant members of the freshwater zooplankton in the Sacramento-San Joaquin delta were those typical of temperate zone rivers—Bosmina and Cyclops among the crustaceans and Keratella, Polyarthra, Trichocerca and Synchaeta among the rotifers. The estuarine or brackish component of the plankton was represented by the copepod Eurytemora affinis and the rotifer Synchaeta bicornis. Abundace of freshwater zooplankton was highest in the San Joaquin River near Stockton, the region with the highest chlorophyll a concentrations and highest temperatures. This was also the region least affected by water project operations, which alter the normal river flow patterns and bring large volumes of zooplankton-deficient Sacramento River water into the San Joaquin River and south delta chanels. Over a seven-year period, abundance of most zooplankton genera was positively correlated with chlorophyll a concentrations and temperature but not with net flow velocity. Only Bosmina had a significant and negative correlation with abundance of a predacious shrimp, Neomysis mercedis. Extreme salinity intrusion in 1977 reduced freshwater zooplankton abundance throughout most of the delta to seven-year lows. All zooplankton groups showed a long-term abundance decline from 1972 to 1978. In the cases of rotifers and copepods, this decline was significantly correlated with a decline in chlorophyll a.

Orsi, J. J., and T.C. Walter. (1991). "Pseudodiaptomus forbesi and P. marinus (Copepoda: Calanoida), the latest copepod immigrants to California's Sacramento-San Joaquin Estuary." Proceedings of the 4th International Conference on Copepoda, Bulletin of the Plankton Society of Japan(Proceedings of the Fourth International Conference on Copepoda): 553-562.

Ongoing zooplankton studies in the Sacramento-San Joaquin Estuary have resulted in several new records for Asian copepods. The identification of Pseudodiaptomus forbesi increases the number of West Pacific species discovered in California to four. Distribution of the species is limited to the upper reaches of the estuary, and varies with temperature and salinity. Reported from China and Japan, this species appears to be restricted to the freshwater estuaries of the Yellow and East China Seas. Another imported species, P. marinus replaces P. forbesi in the more brackish to saline waters in the lower estuary

Orsi, J. J. (1995). Food habits of several abundant zooplankton species in the Sacramento-San Joaquin Estuary.

Orsi, J. J., and W. L. Mecum (1996). Food limitation as the probable cause of a long-term decline in the abundance of Neomysis mercedis the oppossum shrimp in the Sacramento-San Joaquin Estuary. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science AAAS: 375-402.

Neomysis mercedis was sampled from 1968 to 1993 throughout Suisun Bay and the Delta. Adults alternated between large ones in winter and spring and small ones in summer and fall. Annual abundance tended to reach a maximum from May to July. A long-term downtrend in abundance occurred in spring, summer and fall after 1975. Abundance was lowest during the drought years 1987-1992 but did not rise when the drought ended in 1993. Females tended to be smaller in the years oflowest abundance and the percent offemales carrying eggs was low in those years. Five hypotheses for the decline were investigated: (1) reduced concentration by estuarine gravitational

flow and increased seaward loss to tidal pumping, (2) food limitation, (3) rice herbicides, (4) high temperature, (5) export pumping losses. Food limitation of juveniles in the form of reduced phytoplankton concentrations best explained the decline. Food appears to be permanently limited by the grazing of the introduced Asian clam, Pofumocorblilu ulllllrensis. Competition for food by two introduced Asian mysid shrimps may also hamper the recovery of the native mysid population.

Orsi, J. J., and S. Ohtsuka. (1999). "Introduction of the Asian copepods Acartiella sinensis, Tortanus dextrilobatus (Copepoda: Calanoida), and Limnoithona tetraspina (Copepoda: Cyclopoida) to the San Francisco Estuary, California, USA." Plankton Biology and Ecology 46(2): 128-131.
Three new Asian copepods were found in the San Francisco Estuary, California, in 1993: Acartiella sinensis, Tortanus dextrilobatus, and Limnoithona tetraspina. The most likely mode of their introduction is ballast water. These introductions raise the total number of copepod species introduced to the estuary to 8. All are from Asia. No native species are known to have been eliminated by the exotic copepods but the abundance of Eurytemora affinis and Diaptomus spp. has decreased.

Orsi, J. J., A. C. Knutson, Jr., et al. (1979). "An extension of the known range of Neomysis mercedis, the opossum shrimp." California Fish and Game 65: 127-130.

Ort, B., C.S. Cohen, K.E. Boyer, and S. Wyllie-Esheverria (2012). "Genetic diversity within and among eelgrass (Zostera marina) beds in the San Francisco Bay." Journal of Heredity 103(4): 14.
The seagrass Zostera marina is widely distributed in coastal regions throughout much of the northern hemisphere, forms the foundation of an important ecological habitat, and is suffering population declines. Studies in the Atlantic and Pacific oceans indicate that the degree of population genetic differentiation is location dependent. San Francisco Bay, California, USA, is a high-current, high-wind environment where rafting of seed-bearing shoots has the potential to enhance genetic connectivity among Z. marina populations. We tested Z. marina from six locations, including one annual population, within the bay to assess population differentiation and to compare levels of within-population genetic diversity. Using 7 microsatellite loci, we found significant differentiation among all populations. The annual population had significantly higher clonal diversity than the others but showed no detectible differences in heterozygosity or allelic richness. There appears to be sufficient input of genetic variation through sexual reproduction or immigration into the perennial populations to prevent significant declines in the number and frequency of alleles. In additional depth comparisons, we found differentiation among deep and shallow portions in 1 of 3 beds evaluated. Genetic drift, sweepstakes recruitment, dispersal limitation, and possibly natural selection may have combined to produce genetic differentiation over a spatial scale of 3–30 km in Z. marina. This implies that the scale of genetic differentiation may be smaller than expected for seagrasses in other locations too. We suggest that populations in close proximity may not be interchangeable for use as restoration material.

Osti, D., and J. Donovan (2010). Automatically retrieve and analyze CDEC’s hydrologic data collection using web-based get data and GR Tools graphing application. Use a map-based interface to calculate tidal averages and more. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Osti, D., J.R. Burau, J. Donovan, A. Osti, and N. Hemenway (2010). Using time series data for scalar field interpolations. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Working with Jon Burau, USGS and John DeGeorge of RMA, 34 North will demonstrate Baydeltalive.com, a set of web based tools to visualize, process and analyze REAL TIME sensor data and using these tools to create data models for dynamic management and analysis. The demonstration will review each tool including: BDL GET DATA (an automated sensor data aggregator for CDEC/NWIS), GR (Graphing Application), BDL MODEL BUILDER (a data interpolation engine) and NASA Worldwind

(3-D viewer for results presentation). Learn to interpolate the field and analyze temporal and spatial variability as well as create projects from your results and collaborate with colleagues. BDL is a free tool for science collaboration in the California Delta.

Ostrach, D. J., C. Johnson, K. Aceituno, K. Rama, E. Durieux, R. Connon, and I. Werner (2010). Effects of waterborne lipophilic contaminants from locations in the San Francisco Estuary on resident fish. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
In a collaborative research project with United States Fish & Wildlife Service Contaminants Division, USGS and California Department of Fish and Game we investigated the effects of waterborne contaminants on resident fish species using striped bass (Morone saxatilis) as a surrogate for endangered endemic species. The United States Fish and Wildlife Service deployed semi-permeable membrane devices (SPMD) at five sites in the Delta year-round. SPMDs mimic fish bioaccumulation of lipophilic contaminants over a 30 day period. Once retrieved the SPMDs contents are extracted and chemical analysis is performed. Half of the SPMD extract is prepared in a manner suitable for injection into control juvenile striped bass to assess potential physiological effects caused by any lipophilic contaminants from the site. To assess these effects five biochemical and two molecular biomarker assays, histopathology & immunohistochemistry was used. Results indicate 60% of sites were positive for CYP450-1A1 induction indicating sublethal contaminant exposure, vitellogenin expression was found at 25% of sites indicating exposure to estrogenic compounds or their mimics and metallothionein expression at 10% of sites indicating heavy metal exposure or severe oxidative stress. Multiple biomarkers were positive at 35% of the sites demonstrating that several types of xenobiotic exposure were occurring simultaneously. In addition molecular biomarkers HSP-70 and MX were significantly upregulated in 25% and 10% of the sites respectively and likely biologically significant at additional sites. Results from these studies will help characterize spatial and temporal patterns of xenobiotics in the Delta’s water and identify potential adverse effects on resident endangered fish species.

Ostrach, D. J., J. M. Low-Marchelli, et al. (2008). "Maternal transfer of xenobiotics and effects on larval striped bass in the San Francisco Estuary." Proceedings of the National Academy of Sciences 105(49): 19354-19359.
Aquatic ecosystems around the world face serious threats from anthropogenic contaminants. Results from 8 years of field and laboratory investigations indicate that sublethal contaminant exposure is occurring in the early life stages of striped bass in the San Francisco Estuary, a population in continual decline since its initial collapse during the 1970s. Biologically significant levels of polychlorinated biphenyls, polybrominated diphenyl ethers, and current-use/legacy pesticides were found in all egg samples from river-collected fish. Developmental changes previously unseen with standard methods were detected with a technique using the principles of unbiased stereology. Abnormal yolk utilization, brain and liver development, and overall growth were observed in larvae from river-collected fish. Histopathological analyses confirmed and identified developmental alterations. Using this methodology enabled us to present a conclusive line of evidence for the maternal transfer of xenobiotics and their adverse effects on larval striped bass in this estuary.

Paganini, A., Kimmerer, W.J., Stillman, J.H. (2010). "Metabolic responses to environmental salinity in the invasive clam Corbula amurensis " Aquatic Biology 11(2): 139-147.

Painter, B. (1966). "Zooplankton of San Pablo and Suisun Bays." California Department of Fish and Game Fish Bulletin 133: 18-39.

Parchaso, F. and J. K. Thompson (2002). "Influence of Hydrologic Processes on Reproduction of the Introduced Bivalve Potamocorbula amurensis in Northern San Francisco Bay, California." Pacific Science 56(3): 329-346.
Monthly censusing of reproductive condition of the Asian clam Potamocorbula amurensis at four sites in northern San Francisco Bay over a 9-yr period revealed year-to-year differences in local reproductive activity that are associated with

patterns of hydrologic variability. Between 1989 and 1992, Northern California experienced a drought, whereas the period between 1993 and 1998 was marked by a mix of wet and dry years. We took advantage of the extreme year-to-year differences to examine reproductive responses to river inflow patterns. Populations of P. amurensis at the upstream sites in Suisun Bay and Carquinez Strait were more reproductively active during wet years than dry years. Conversely, at the downstream site in San Pablo Bay, the population was more reproductively active during dry years than wet years. We suggest that the different reproductive patterns observed reflect the clam's response to different sources of food. During wet years, organic matter from the rivers augments food supplies in Suisun Bay. During dry years, when inflow into the San Francisco Bay Estuary from the rivers is reduced, water transported from the adjacent ocean into the estuary as far as San Pablo Bay provides a supplemental food supply for the local production. The populations take advantage of these spatially distinct food supplies by initiating and maintaining local reproductive activity. We conclude that the ability of P. amurensis to consume and use various types of food to regulate its reproductive activity is part of the reason for its success as an invasive species.

Parker, A., R. Dugdale, F. Wilkerson, and A. Marchi (2010). Biogeochemical processing of anthropogenic ammonium in the Sacramento River and the northern San Francisco Estuary. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Like estuaries around the world, the San Francisco Bay estuary (SFE) receives large anthropogenic loads of inorganic nutrients as a result of increased population growth; inorganic nitrogen (N) comes primarily from municipal wastewater treatment plant (WWTP) discharge in the form of ammonium (NH4). In contrast to other eutrophic estuaries, the SFE generally does not exhibit nuisance blooms or localized hypoxia but rather phytoplankton respond to increased NH4 loading with diminished nutrient uptake, reduced primary production and biomass, and altered phytoplankton community composition all of which potentially act to reduce food web support for pelagic organism decline (POD) species. The present study investigated the consequences for river and estuarine phytoplankton of WWTP discharge along a 150-km transect in the Sacramento River and northern SFE. Consistent with previous results for the northern SFE, phytoplankton nitrogen uptake shifted from a nitrate (NO3)-based system to one supported by NH4 immediately downstream of the WWTP discharge and the sum of inorganic N uptake and carbon uptake declined with elevated NH4. The result was a U-shaped pattern of primary productivity and chlorophyll with maxima found in the river above the outfall and at Suisun and San Pablo Bay to the west and a minimum found in the river downstream of the WWTP, essentially a mirror image of distribution of NH4 concentrations. Phytoplankton NH4 uptake rates and nitrification rates were insufficient to appreciably reduce NH4 concentrations in the Sacramento River resulting in a large export of anthropogenic NH4 to habitats critical for POD species in the SFE Delta and in Suisun Bay. These results suggest an unintended consequence of the Clean Water Act of 1972 and the conversion of sewage treatment to the secondary level discharging N as NH4.

Parker, A., W. Kimmerer, et al. (2012). "Reevaluating the Generality of an Empirical Model for Light-Limited Primary Production in the San Francisco Estuary." Estuaries and Coasts 35(4): 930-942.

Parker, A. E., R. C. Dugdale, et al. (2012). "Elevated ammonium concentrations from wastewater discharge depress primary productivity in the Sacramento River and the Northern San Francisco Estuary." Marine Pollution Bulletin 64(3): 574-586.

Parker, M., J.G. Thompson, R.R. Reynolds Jr., M.D. Smith, and W.E. Templin (1995). Ground-water management in California during periods of decreasing water supplies and increasing water demands. Water Resources and Environmental Hazards: Emphasis on hydrologic and cultural insight in the Pacific Rim, American Water Resources Association Annual Summer Symposium, Honolulu, HI, American Water Resources Association.

Parker, M., J.G. Thompson, R.R. Reynolds Jr., M.D. Smith, and W.E. Templin (1995). Water-use conservation forecasts for the Salinas River Valley basin management plan:

Estimates for block pricing. "Water Resources and Environmental Hazards: Emphasis on Hydrologic and Cultural Insight in the Pacific Rim" American Water Resources Association Annual Summer Symposium, Honolulu, HI, American Water Resources Association.

Parker, V. T., J. Callaway, E. Herbert, L. Schile, V. Vredenburg, M. Vasey, E. Borgnis, M. Kelly, and D. Talley (2010). How climate change may impact San Francisco Bay-Delta wetlands and their links to pelagic food webs. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
San Francisco Bay-Delta wetlands are predicted to experience substantial shifts in salinity and inundation over the next century. Summer salinities will increase due to reduced freshwater flows, sea-level rise, and increased summer temperatures; inundation rates will increase as sea-level rise outpaces marsh accretion. While these shifts are predicted in estuaries around the country, the impacts will differ significantly between temperate systems and the Mediterranean-type climate system found in the SF Bay-Delta, with greater importance of salt stress in Mediterranean systems. We are completing a multi-year study that evaluates the predicted effects of climate change on marsh dynamics, investigating plant species distributions, primary productivity, decomposition rates, sediment accretion, and food web dynamics across the estuary. Freshwater marshes have higher rates of both productivity and diversity (>60 species, 2440 g m-2) than brackish (24-50 species, 900-1400 g m-2) or salt marshes (10-17 species, 270-700 g m-2), but wetlands show specific inter- and intra-site variability in diversity and productivity that is strongly correlated with inundation and salinity. Sediment accretion and plant decomposition rates also indicate differences in the importance of mineral versus organic matter inputs to marsh accretion across the gradient from salt to freshwater marshes, with greater importance of mineral matter at the salt water end of the gradient. Carbon and nitrogen stable isotope data suggest a dependence of resident fishes on the productivity of specific assemblages within marshes, indicating that pelagic consumers will be impacted by changes in marsh plant communities in response to changes in salinity and inundation.

Parsons, L., G. Kamman, and A. Ryan (2010). Improving watershed health through large-scale wetland restoration. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Wetlands are believed to play many important functions for both wildlife and humans. However, these functions are lost when wetlands are altered. Located directly north of San Francisco Bay, Tomales Bay lost 50% of its wetlands in the 1940s when a large marsh was leveed for a dairy ranch operation. In 2000, the National Park Service bought this dairy for a 613-acre wetland restoration project, which was implemented in 2007-2008. The Park Service believed that restoration could not only improve quality of the degraded wetlands within the ranch, but improve overall watershed health by increasing habitat for wildlife, as well as improve downstream water quality. While Tomales Bay is often viewed as pristine and is a Ramsar Wetland of International Importance, its waters have been impacted by leaking septic tanks, agriculture, mercury, and oil spills and are designated as impaired under Section 303(d). Two-thirds of the Bay’s freshwater input and principal contaminant source comes from tributaries upstream of the Giacomini Ranch, which will now be able to be filtered by the reconnected floodplains. To determine restoration success, the Park Service developed an innovative long-term pre- and post-project monitoring program that incorporates both the Project Area and reference wetlands. Monitoring in the first year after restoration indicates that many of the improvements anticipated to occur over the long-term after conversion of pastureland to marsh are already occurring, including substantial reduction in pollutant concentrations; increases in bird and other wildlife use; changes in the species using the Project Area; reductions in non-native species; reductions in non-native species; and rapid replacement of pasture grasses with marsh plants. With so many of the San Francisco Bay –Delta restoration projects still in the planning or early implementation phase, this recently completed project provides important comparative information to improve planning and implementation of Bay-Delta restoration efforts.

Pasternack, G. B. and K. J. Brown (2006). "Natural and anthropogenic geochemical signatures of floodplain and deltaic sedimentary strata, Sacramento-San Joaquin Delta, California, USA." Environmental Pollution 141(2): 295-309.

The geochemical history of an upper deltaic plain pending tidal wetland restoration was reconstructed to assess remobilization of redox-sensitive constituents in sediment, identify depositional processes promoting geochemical retention, and determine the extent of contamination with Hg, As, Pb, Cu, and Zn. Three 12-14-m sediment cores were analyzed for bulk sediment geochemistry using ICP-AES. Rather than showing similar stratigraphic and geochemical down- core trends, cores had a unique record indicative of strong spatial gradients in deposition processes. Each strata type (e.g. basal clay, sand channel, distal floodplain, and agriculturally impacted surficial horizon) had a unique geochemical "fingerprint". The agriculturally impacted surficial layer showed high [Hg], [As], and [Pb]. The significance is that a restored upper delta will have a complex geomorphology defying conventional criteria of "success" in a restoration framework. Also, there is a significant risk of generating toxic, bio-available CH sub(3)Hg super(+) that would be hazardous to fish. Geomorphic-geochemical linkages on an upper deltaic plain have dynamics that defy expectations for achieving restoration "success".

Patrick, W. H. and R. D. Delaune (1990). "Subsidence, accretion, and sea level rise in South San Francisco Bay marshes." Limnology and Oceanography 35(6): 1389-1395.

Accelerated sea level rise that is predicted to occur as a result of the greenhouse effect is likely to have a significant effect on the world's salt marshes. For salt-marsh vegetation to remain productive and even to survive in a period of rising sea level, the marsh must accrete sufficient sediment to maintain the marsh surface within an appropriate tidal range. Accretion and subsidence were studied in three south San Francisco Bay salt marshes that differed greatly in subsidence over the past few decades. Marsh accretion as a result of sedimentation and peat of formation has been able to compensate for high rates of subsidence and the low rate of sea level rise and to maintain the elevation of the marsh surface above mean high water (MHW).

Paulson, S. C., and J.E. List (1997). "A study of transport and mixing in natural waters using ICP-MS: Water-particle interactions." Water, Air and Soil Pollution 99(1-4): 149-156.

Water-particle interactions often may result in non-conservative chemical behavior when waters from different sources mix with one another. The results presented in this paper address the role of these interactions in freshwater and estuarine mixing and support a larger study to develop a method to help resolve flow distribution and water quality questions in surface waters using a source water “fingerprinting” technique. Inductively coupled plasma-mass spectrometry (ICP-MS) is used to “fingerprint” each water source based upon the concentrations and relative proportions of elements in that source. Estimates can then be made of the fractions of various “fingerprinted” waters in water samples that contain a mixture of source waters. Such estimates depend upon the selection of tracers that behave conservatively during mixing; in this paper, results to establish the maximum particle exchange capacity and conservative mixing behavior are presented for samples collected from the Sacramento River-San Francisco Bay-Delta estuary. Elements likely to behave conservatively include boron, sodium, magnesium, potassium, calcium, strontium, and molybdenum.

Pearce, J., J. Sowers, C. Brossy, and K. Kelson (2010). Surficial geology of the northern Sacramento – San Joaquin Delta, recognizing deposits, landforms, and sedimentary environments and their relevance to science and engineering. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Detailed geologic mapping of surficial and near-surface geologic deposits and their associated landforms documents a range of sedimentary environments that characterized the northern Sacramento-San Joaquin Delta before levee construction and agricultural development of the early 20th century. Working from historical maps and aerial photography, and limited subsurface data, we recognize a variety of deposits and related landforms, such as river crevasse splays, natural levees, distributary channels, sloughs, intermittent ponds or sinks, marshes and wetlands. Surficial deposits and sediment character change both as a result of the downstream transition through fluvial, deltaic, and estuarine environments, and with lateral proximity to sediment-laden streams. The Sacramento River in the northern delta is bordered by natural levees of fine sand and silt approximately two kilometers wide that forms high ground 5 to 15 feet above the surrounding flood basin. The natural levee grades downslope into the floodbasin, a low, marshy area where clay and silt settle out of slow-moving floodwaters. Westward, the flood basin slopes gently upward toward alluvial fans built by Coast Range streams. Southward into the Delta, the natural levee deposits become siltier and the intervening flood basin deposits more clay- and organic-rich. Natural levees extend through the Delta adjacent to the river and other major channels and grade laterally into silty clay, then peat. The character and relationships of the geologic deposits has implications for engineering and scientific studies. The stability of artificial levees within the Delta partially is a function of the nature of the underlying deposits. In addition, surficial mapping provides a framework for understanding the rich tapestry of historical geomorphic environments that were created by these processes and process linkages. The historical geomorphic environments, along with the associated ecologic habitats, have been permanently altered by ditching, draining, deposition of hydraulic mining debris, channelization, levee construction, and agriculture. The detailed surficial geologic mapping thus provides key data to document deposits, past processes, and geomorphic environments.

Pearson, D. (1989). Survey of fishes and water properties of South San Francisco Bay, California, 1973-82, Noaa Technical Report NMFS 78; U.S. Dept. of Commerce.

Penry, D. L. (2000). "Digestive kinematics of suspension-feeding bivalves: modeling and measuring particle-processing in the gut of Potamocorbula amurensis." Marine Ecology Progress Series 197: 181-192.
Particle digestion in lamellibranch bivalves is partitioned between 2 paths, an 'intestinal' path through the stomach and intestine and a 'glandular' path through the stomach, digestive gland and intestine. In the Asian clam Potamocorbula amurensis, the relative importance of the intestinal path increases compared to the glandular path as food availability and ingestion rate increases. The effects of changes in food availability and ingestion rate on digestive partitioning are at least as important as the effect of changes in diet observed by other investigators. Analyses of residence-time distributions of inert 9 and 44 mu m particle tracers show that the gut of P. amurensis can be modeled as an ideal mixing reactor (stomach and digestive gland) and an ideal plug-flow reactor (intestine) in series. This model appears to be valid for the processing of particles less than or equal to 9 mu m in size. For particles of greater than or equal to 15 mu m, the ideal mixing component of the model must be modified to account for channeling of particles through the stomach to the intestine. Larger particles can enter the digestive gland, but are probably not phagocytized for intracellular digestion. Instead they may clog the ducts and tubules, limiting phagocytosis of smaller particles and potentially reducing the extent of digestion and absorption. Mixing, and the resultant intragut particle-sorting thus appear to be necessary components of a digestive strategy that incorporates intracellular digestion.

Pereira, W. E., F.D. Hostettler, J.R. Cashman, and R.S. Nishioka (1994). "Occurrence and distribution of organochlorine compounds in sediment and livers of striped bass (Morone saxatilis) from the San Francisco Bay-Delta Estuary." Marine Pollution Bulletin 28(7): 434-441.
A preliminary assessment was made in 1992 of chlorinated organic compounds in sediments and in livers of striped bass from the San Franciso Bay-Delta Estuary. Samples of sediment and striped bass livers contained DDT (ethane, 1,1,1-trichloro-2,2-bis (p-chlorophenyl)-) and its degradation products, DDD (ethane, 1,1-dichloro-2,2-bis(p-chlorophenyl)-) and DDE (ethylene, 1,1-dichloro-2,2-bis (p-chlorophenyl)-); PCBs (polychlorinated biphenyls); alpha and gamma chlordane, and cis and trans nonachlor. In addition, the livers of striped bass contained small concentrations of DCPA (dimethyl tetrachloroterephthalate), a pre-emergent herbicide. Agricultural run-off from the Sacramento and San Joaquin Rivers, as well as atmospheric deposition, are probably responsible for a low

chronic background of DDT in sediments throughout San Francisco Bay. Larger concentrations of DDT in sediment near Richmond in the Central Bay, and Coyote Creek in the South Bay may be derived from point sources. Ratios of pentachloro isomers of PCBs to hexachloro isomers in the South Bay sediments were different from those in the Central and North Bay, suggesting either differences in microbial activity in the sediments or different source inputs of PCBs. Concentrations of alpha chlordane in livers of striped bass were greater than those of gamma chlordane, which suggests a greater environmental stability and persistence of alpha chlordane. Trans nonachlor, a minor component of technical chlordane, was present in greater concentrations than alpha and gamma chlordane and cis nonachlor. Trans nonachlor is more resistant to metabolism than alpha and gamma chlordane and cis nonachlor, and serves as an environmentally stable marker compound of chlordane contamination in the estuary. Chlorinated organic compounds have bioaccumulated in the livers of striped bass. These compounds may contribute to the decline of the striped bass in San Francisco Bay-Delta Estuary.

Pereira, W. E., J.L. Domagalski, F.D. Hostettler, L.R. Brown, and J.B. Rapp (1996). "Occurrence and accumulation of pesticides and organic contaminants in river sediment, water and clam tissues from the San Joaquin River and tributaries, California." Environmental Toxicology and Chemistry 15(2): 172-180.

A study was conducted in 1992 to assess the effects of anthropogenic activities and land use on the water quality of the San Joaquin River and its major tributaries. This study focused on pesticides and organic contaminants, looking at distributions of contaminants in water, bed and suspended sediment, and the bivalve Corbicula fluminea. Results indicated that this river system is affected by agricultural practices and urban runoff. Sediments from Dry Creek contained elevated concentrations of polycyclic aromatic hydrocarbons (PAHs), possibly derived from urban runoff from the city of Modesto; suspended sediments contained elevated amounts of chlordane. Trace levels of triazine herbicides atrazine and simazine were present in water at most sites. Sediments, water, and bivalves from Orestimba Creek, a westside tributary draining agricultural areas, contained the greatest levels of DDT (1,1,1-trichloro-2,2-bis[p-chlorophenyl]ethane), and its degradates DDD (1,1-dichloro-2,2-bis[p-chlorophenyl]ethane), and DDE (1,1-dichloro-2,2-bis[p-chlorophenyl]ethylene). Sediment adsorption coefficients (Koc), and bioconcentration factors (BCF) in Corbicula of DDT, DDD, and DDE at Orestimba Creek were greater than predicted values. Streams of the western San Joaquin Valley can potentially transport significant amounts of chlorinated pesticides to the San Joaquin River, the delta, and San Francisco Bay. Organochlorine compounds accumulate in bivalves and sediment and may pose a problem to other biotic species in this watershed.

Pereira, W. E., F.D. Hostettler, S.N. Luoma, A. van Geen, C.C. Fuller, and R.J. Anima (1999). "Sedimentary record of anthropogenic and biogenic polycyclic aromatic hydrocarbons in San Francisco Bay, California." Marine Chemistry 64(1-2): 99-113.

Dated sediment cores collected from Richardson and San Pablo Bays in San Francisco Bay were used to reconstruct a history of polycyclic aromatic hydrocarbon (PAH) contamination. The sedimentary record of PAHs in Richardson Bay shows that anthropogenic inputs have increased since the turn of the century, presumably as a result of increasing urbanization and industrialization around the Bay Area. Concentrations range from about 0.04–6.3 µg g−1. The dominant origin of the PAHs contributing to this modern contamination is from combustion processes. Depth profiles in San Pablo Bay indicate higher concentrations of PAHs since the 1950s than during the late 1800s, also presumably resulting from an increase in urbanization and industrialization. Total PAHs in San Pablo Bay range from about 0.04–1.3 µg g−1. The ratios of methylphenanthrenes/phenanthrene and (methylfluoranthenes+methylpyrenes)/fluoranthene were sensitive indicators of anthropogenic influences in the estuary. Variations in the ratio of 1,7-dimethylphenanthrene/2,6-dimethylphenanthrene indicate a gradual replacement of wood by fossil-fuel as the main combustion source of PAHs in San Francisco Bay sediments. The profile of perylene may be an indicator of eroding peat from marshlands.

Pereira, W. E., F. D. Hostettler, et al. (1992). "Bioaccumulation of Hydrocarbons

Derived from Terrestrial and Anthropogenic Sources in the Asian Clam, Potamocorbula-Amurensis, in San-Francisco Bay Estuary." Marine Pollution Bulletin 24(2): 103-109.
An assessment was made in Suisun Bay, California, of the distributions of hydrocarbons in estuarine bed and suspended sediments and in the recently introduced asian clam, Potamocorbula amurensis. Sediments and clams were contaminated with hydrocarbons derived from petrogenic and pyrogenic sources. Distributions of alkanes and of hopane and sterane biomarkers in sediments and clams were similar, indicating that petroleum hydrocarbons associated with sediments are bioavailable to Potamocorbula amurensis. Polycyclic aromatic hydrocarbons in the sediments and clams were derived mainly from combustion sources. Potamocorbula amurensis is therefore a useful bioindicator of hydrocarbon contamination, and may be used as a biomonitor of hydrocarbon pollution in San Francisco Bay.

Pereira, W. E., F. D. Hostettler, et al. (1996). "Distributions and fate of chlorinated pesticides, biomarkers and polycyclic aromatic hydrocarbons in sediments along a contamination gradient from a point-source in San Francisco Bay, California." Marine Environmental Research 41(3): 299-314.
The distribution and fate of chlorinated pesticides, biomarkers, and polycyclic aromatic hydrocarbons (PAHs) in surficial sediments along a contamination gradient in the Lauritzen Canal and Richmond Harbor in San Francisco Bay was investigated. Compounds were identified and quantified using gas chromatography-ion trap mass spectrometry. Biomarkers and PAHs were derived primarily from weathered petroleum. DDT was reductively dechlorinated under anoxic conditions to DDD and several minor degradation products, DDMU, DDMS, and DDNU. Under aerobic conditions, DDT was dehydrochlorinated to DDE and DBP. Aerobic degradation of DDT was diminished or inhibited in zones of high concentration, and increased significantly in zones of lower concentration. Other chlorinated pesticides identified in sediment included dieldrin and chlordane isomers. Multivariate analysis of the distributions of DDTs suggested that there were probably two sources of DDD. In addition, DDE and DDMU are probably formed by similar mechanisms, i.e. dehydrochlorination. A steep concentration gradient existed from the Canal to the Outer Richmond Harbor, but higher levels of DDD than those found in the remainder of the Bay indicated that these contaminants are transported on particulates and colloidal organic matter from this source into San Francisco Bay. Chlorinated pesticides and PAHs may pose a potential problem to biota in San Francisco Bay.

Perry, R., J. Skalski, P. L. Brandes, and J. R. Burau (2010). Effects of tides, river flow, and gate operations on entrainment of juvenile Chinook salmon into the interior Sacramento-San Joaquin Delta. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Recent acoustic telemetry studies have revealed that survival of juvenile late-fall Chinook salmon depends on the migration route fish use to negotiate the Sacramento-San Joaquin River Delta. Fish entering the interior Delta, where pumping stations are located, survive at lower at a rate than fish using other routes. Consequently, the proportion of the population entrained into the interior Delta affects population-level survival. We examined the effect of tidal fluctuations, river inputs, and operation of the Delta Cross Channel gates on entrainment of juvenile salmon from the Sacramento River into the interior Delta via the Delta Cross Channel and Georgiana Slough. We found that the probability of entering the interior Delta depended strongly on the tidal stage when fish arrived at the river junction, especially when mean daily discharge was low. Fish arriving at the river junction during flood tides had a high probability of entering the interior Delta whereas fish arriving during ebb tides had a low probability of entrainment. As mean river discharge increased, tidal forces were dampened, which reduced the effect of flood tides on entrainment. Closing the Delta Cross Channel gates decreased the probability of fish entering the interior Delta, but by less than expected given the reduction in flow entering the interior Delta. We illustrate how our migration routing model can be used to evaluate the effect of alternative water management actions on entrainment of fish into the interior Delta.

Perry, R. (2010). Survival of juvenile late-fall chinook salmon using different migration routes to negotiate the Sacramento-San joaquin River Delta. 6th Biennial

Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Peterson, D., S. Hager, et al. (1988). Riverine C, N, Si and P transport to the coastal ocean: an overview. Lecture Notes on Coastal and Estuarine Studies. B.-O. Jansson. New York, Springer-Verlag: 227-256.

Peterson, D. H., T. Conomos, W.W.J. Broenkow, and P.C. Doherty (1975). "Location of the non-tidal current null zone in northern San Francisco Bay." Estuarine Coastal Marine Science 3(1): 1-11.
Variations in Sacramento-San Joaquin River discharge into northern San Francisco Bay causes shifts in location of the bottom density current null zone. At a river flow of 2000 m3/s this null zone is approximately 20 km from the seaward end of the estuary, whereas at a river flow of 100 m3/s it is 80 km from the seaward end; the corresponding distances of salinity penetration are approximately 40 and 90 km from the seaward end. Seaward of the null zone, during low (summer) river discharge conditions, the inward-flowing bottom density current appears typically strong (5-15 cm/s) relative to the outward-flowing river current (river discharge per unit cross-channel area) of <2 cm/s. Landward from this null zone the average river current increases with decreasing cross-channel area. This circulation implies that during the summer water within the null zone has the longest average advective replacement time relative to water seaward or landward of the null zone.

Peterson, D. H. (1979). Sources and sinks of biologically reactive oxygen, carbon, nitrogen, and silica in northern San Francisco Bay. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 175-193.

Peterson, D. H., and J.F. Festa (1984). "Numerical simulation of phytoplankton productivity in partially mixed estuaries." Estuarine, Coastal and Shelf Science 19(5): 563-589.
A two-dimensional steady-state model of light-driven phytoplankton productivity and biomass in partially mixed estuaries has been developed. Effects of variations in river flow, suspended sediment concentration, phytoplankton sinking, self-shading and growth rates on distributions of phytoplankton biomass and productivity are investigated. Numerical simulation experiments show that biomass and productivity are particularly sensitive to variations in suspended sediment concentrations typical of natural river sources and to variations in loss rates assumed to be realistic but poorly known for real systems. Changes in the loss rate term within the range of empirical error (such as from dark bottle incubation experiments) cause phytoplankton biomass to change by a factor of two. In estuaries with adequate light penetration in the water column, it could be an advantage for phytoplankton to sink. Species that sink increase their concentration and form a phytoplankton maximum in a way similar to the formation of the estuarine turbidity maximum. When attenuation is severe, however, sinking species have more difficulty in maintaining their population.

Peterson, D. H., D.R. Cayan, J.F. Festa, F.H. Nichols, R.A. Walters, J.V. Slack, S.E. Hager, and L.E. Schemel (1989). Climate variability in an estuary: Effects of river flow on San Francisco Bay. Aspects of climate variability in the Pacific and Western Americas. D. H. Peterson. Washington D.C., American Geophysical Union A.G.U. Geophysical Monograph 55: 419-442.
A simple conceptual model of estuarine variability in the context of climate forcing has been formulated using up to 65 years of estimated mean-monthly delta flow, the cumulative freshwater flow to San Francisco Bay from the Sacramento-San Joaquin River, and salinity observations near the mouth, head, mid-estuary, and coastal ocean. Variations in delta flow, the principal source of variability in the bay, originate from anomalous changes in northern and central California streamflow, much of which is linked to anomalous winter sea level pressure (“CPA”) in the eastern Pacific. In years when CPA is strongly negative, precipitation in the watershed is heavy, delta flow is high, and the bay's salinity is low; similarly, when CPA is strongly positive, precipitation is light, delta flow is low, and the bay's salinity is high. Thus the pattern of temporal variability in atmospheric

pressure anomalies is reflected in the streamflow, then in delta flow, then in estuarine variability.
Estuarine salinity can be characterized by river to ocean patterns in annual cycles of salinity in relation to delta flow. Salinity (total dissolved solids) data from the relatively pristine mountain streams of the Sierra Nevada show that for a given flow, one observes higher salinities during the rise in winter flow than on the decline. Salinity at locations throughout San Francisco Bay estuary are also higher during the rise in winter flow than the decline (because it takes a finite time for salinity to fully respond to changes in freshwater flow). In the coastal ocean, however, the annual pattern of sea surface salinity is reversed: lower salinities during the rise in winter flow than on the decline due to effects associated with spring upwelling. Delta flow in spring masks these effects of coastal upwelling on estuarine salinity, including near the mouth of the estuary and, in fact, explains in a statistical sense 86 percent of the variance in salinity at the mouth of the estuary. Some of the variations in residual salinity in the bay not explained by delta flow appear to correlate with variability in coastal ocean properties. Interestingly CPA correlates also with anomalous sea surface salinity in the coastal ocean adjacent to the bay, especially in spring (albeit through a different mechanism than streamflow). For instance, when the atmospheric pressure anomaly as indicated for streamflow is high, the coastal ocean upper-layer Ekman transport is probably in the offshore direction resultingin higher sea surface salinities along the coast (with a phase lag). This circulation corresponds, in direction, to density driven estuarine circulation. In contrast a low atmospheric pressure regime leads to an onshore surface transport, and therefore opposes estuarine circulation.
The influence of variations in delta flow on estuarine/phytoplankton/biochemical dynamics can be illustrated with numerical simulation models. For example, when riverflow is high the resulting low estuarine water residence time limits phytoplankton biomass and the observed effects of phytoplankton productivity on estuarine biochemistry are minimal. When riverflow is low but suspended sediment concentrations are high, light becomes a more important factor limiting phytoplankton biomass than residence time and effects of phytoplankton productivity on estuarine biochemistry are also minimal. When both riverflow and suspended sediment concentrations are low, phytoplankton biomass increases and phytoplankton productivity emerges as a major control on estuarine biochemistry: phytoplankton activity draws down and maintains very low ambient concentrations of dissolved silica and partial pressures of carbon dioxide (shifting pH to higher values). However, after an extended period of very low delta flow the major controls on estuarine biochemistry appear to change, possibly because benthic exchange processes (both sources and sinks) strengthen as salinity rises and benthic filter-feeding invertebrates migrate upstream with increasing salinity.

Peterson, D. H., D.R. Cayan, J. DiLeo, M. Noble, and M. Dettinger (1995). "The role of climate in estuarine variability." American Scientist 83(1): 58-67.

One of the more awkward facts of California's hydrology is that 70 percent of the state's annual runoff of fresh water occurs north of Sacramento, whereas 80 percent of the state's water consumption takes place south of that city. To supply the south, increasing amounts of water have been diverted from the Sacramento and San Joaquin rivers, greatly reducing freshwater inflows to San Francisco Bay. These diversions have been of great interest to scientists concerned with the health of the bay, which is tied to fluctuations in salinity. They have looked closely at the flow from the Sacramento-San Joaquin Delta, the complex of islands and channels where the two rivers meet, which accounts for 90 percent of the freshwater inflow to the bay.

But sorting out the causes of the water-flow and salinity fluctuations in the delta and San Francisco Bay, and in many other estuary systems, is not a simple matter. A wide variety of climatic and human influences act on the estuary. Fluctuations in climate would cause freshwater inflow to the bay to vary dramatically from year to year, even without large diversions upstream. And the diversions themselves vary from year to year.

It is not surprising, given all these influences, that the salinity of the bay is highly variable and has been rising. Between winter and summer most years, salinity varies as much as 10 parts per thousand--an enormous fluctuation when one considers that the salinity of coastal ocean water is normally just over 33 parts per thousand. And bay salinity varies by a similar amount from year to year. Over the longer term--a matter of particular concern--spring salinities have been slowly rising over the past few decades, increasing by 3 parts per thousand since 1941.

The diversion of fresh water is a large part of the story. Largely because of diversions for agricultural uses, it is estimated that the delta flow is less than 50 percent of its volume in 1850 (although estimates are uncertain because flows were not measured before development took place). Diversion is clearly responsible for much of the salinity increase, but does it account for all of it? To what extent, for instance, might the salinity trend reflect natural fluctuations, such as winter warming or a shift to weather patterns that favor the upwelling of saline water off the coast?

It is one thing to ask these questions and quite another to answer them. Distinguishing short- and long-term anthropogenic trends from the fluctuations of a natural system can be very difficult. To make this distinction in estuarine dynamics we must take a much broader view of estuarine systems than scientists have usually taken.

Peterson, D. H., D.R. Cayan, M.D. Dettinger, M.A. Noble, L.G. Riddle, L.E. Schemel, R.E. Smith, R.J. Uncles, and R.A. Walters (1996). San Francisco Bay salinity: observations, numerical simulation, and statistical models. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science
AAAS: 9-34.
Understanding the variability of salinity in San Francisco Bay is a key to defining the bay’s physics, chemistry, and biology. This paper is in part a literature review and in part uses decades of observations supported by results from statistical-dynamical and numerical models to describe salinity variability in San Francisco Bay. Findings include the following: (1) Freshwater delta flow (DF) is the master control on mean-monthly salinity in the Bay, (2) Salinity fluctuations are reasonably well modeled on mean monthly and daily time scales, (3) Hysteresis is observed in both data and models, (4) Coastal ocean processes affect salinity in the Bay and vice versa, (5) statistical dynamical models driven by variations in hourly sea surface height near the mouth can estimate about 80% of the hourly salinity variance near mid- estuary at tidal time scales during low relatively uniform delta flow, and (6) Climate (small effect) as well as freshwater diversions (large effect) control long-term (decadal) salinity variations.

Peterson, D. H., J. F. Festa, et al. (1978). "Numerical simulation of dissolved silica in the San Francisco Bay." Estuarine and Coastal Marine Science 7: 99-116.
A two-dimensional (vertical) steady-state numerical model that simulates water circulation and dissolved-silica distributions is applied to northern San Francisco Bay. The model (1) describes the strong influence of river inflow on estuarine circulation and, in turn, on the biologically modulated silica concentration, and (2) shows how rates of silica uptake relate to silica supply and mixing rates in modifying a conservative behavior. Longitudinal silica distributions influenced by biological uptake (assuming both vertically uniform and verticaly decreasing uptake situations) show that uptake rates of 1 to 10 mu g-at. 1 SUP--1 day SUP--1 are sufficient to depress silica concentrations at river inflows to 100-400 m SUP-3 s SUP--1 , respectively, and that the higher rates appear ineffective at inflows above 400 m SUP-3 s SUP--1 . The simulations further indicate that higher silica utilization in the null zone is not essential to depress silica concentrations strongly there. Advective water-replacement times at river inflows of 400, 200 and 100 m SUP-3 s SUP--1 are computed to be <25, 45 and 75 days, respectively, for a 120-km estuary-river system.

Peterson, D. H., M. Noble, et al. (1993). Suspended sediment in San Francisco Bay, California - recent history and available data sets, U.S. Geological Survey Water Resources Investigations Report 93-4128.

Peterson, D. H., R. E. Smith, et al. (1985). "Interannual variability in dissolved inorganic nutrients in Northern San Francisco Bay Estuary." Hydrobiologia 129: 37-58.

Peterson, D. H., I. Stewart, et al. (2008). "Principal Hydrologic Responses to Climatic and Geologic Variability in the Sierra Nevada, California " San Francisco Estuary and Watershed Science 6(1): Article 3.
Sierra Nevada snowpack is a critical water source for California’s growing population and agricultural industry. However, because mountain winters and springs are warming, on average, precipitation as snowfall relative to rain is decreasing, and snowmelt is earlier. The changes are stronger at mid-elevations than at higher elevations. The result is that the water supply provided by snowpack is diminishing. In this paper, we describe principal hydrologic responses to climatic and spatial geologic variations as gleaned from a series of observations including snowpack, stream-flow, and bedrock geology. Our analysis focused on peak (maximum) and base (minimum) daily discharge of the annual snowmelt-driven hydrographs from 18 Sierra Nevada watersheds and 24 stream gage locations using standard correlation methods. Insights into the importance of the relative magnitudes of peak flow and soil water storage led us to develop a hydrologic classification of mountain watersheds based on runoff versus base flow as a percentage of peak flow. Our findings suggest that watersheds with a stronger base flow response store more soil water than watersheds with a stronger peak-flow response. Further, the influence of antecedent wet or dry years is greater in watersheds with high base flow, measured as a percentage of peak flow. The strong correlation between 1) the magnitude of peak flow, and 2) snow water equivalent can be used to predict peak flow weeks in advance. A weaker but similar correlation can be used to predict the magnitude of base flow months in advance. Most of the watersheds show a trend that peak flow is occurring earlier in the year.

Peterson, H., and M. Vayssieres (2004). Cross-channel variability in benthic habitat: Old River. IEP Newsletter. 17: 7.

Peterson, H. A. (2002). Long-term benthic community change in a highly invaded estuary, San Francisco State University.

Peterson, H. A. a. M. V. (2010). "Benthic Assemblage Variability in the Upper San Francisco Estuary: A 27 Year Retrospective." San Francisco Estuary and Watershed Science 8(1).
We used multivariate methods to explore changes in benthic assemblage structure over 27 years (1977–2003) at four monitoring stations located along a salinity gradient in the upper San Francisco Estuary. Changes in benthic assemblage composition were assessed relative to hydrologic variability and to the presence of the high-impact invader Corbula amurensis in the estuary. We also explored the composition of benthic assemblages during a recent collapse of several pelagic populations in the upper estuary. Our results show that the Corbula invasion had both direct and indirect effects on the benthos in the estuary, causing significant changes in assemblage structure. We found no unprecedented patterns of benthic assemblage composition during the period of the Pelagic Organism Decline (2000–2003) in the upper estuary. Hydrologic variability was associated with significant changes in benthic assemblage composition at all locations. Benthic assemblage composition was more sensitive to mean annual salinity than other local physical conditions. That is, benthic assemblages were not geographically static, but shifted with salinity, moving down-estuary in years with high delta outflow, and up-estuary during years with low delta outflow, without strong fidelity to physical habitat attributes such as substrate composition or location in embayment vs. channel habitat. Organism abundance and species richness showed a bi-modal distribution along the salinity gradient, with lowest abundance and richness in the 5 to 8 psu range. We conclude that the continuity of benthic assemblages and community metrics along the salinity gradient is a powerful and necessary context for understanding historical variability in assemblage composition at geographically static monitoring stations.

Petreas, M. X., T. Wiesmuller, F.H. Palmer, J.J. Winkler, and R.D. Stephens (1992). "Aquatic life as biomonitors of dioxin-furan and coplanar polychlorinated biphenyl contamination in the Sacramento-San Joaquin River Delta." Chemosphere 25(4): 621-631.
A pilot study was designed to investigate the extent, magnitude and source of polychlorinated dibenzodioxin and furan (PCDD/F) and coplanar polychlorinated biphenyl (PCB) contamination using aquatic life as biomonitors. The study focused around a bleached pulp and paper mill operating, along with other industrial facilities, near the confluence of the Sacramento and San Joaquin rivers (Delta) in northern California. Four locations were selected for sampling: two upstream from the plant (one on each river), one in the vicinity of the plant and one downstream from the plant. Because of the salinity gradient of the riverine system, no single fish or bivalve species could be collected, but multiple comparisons were made instead. The target species were selected on the basis of their abundance and localized feeding range. Clams were transplanted in the three freshwater locations and retrieved two months later, while resident mussels were collected from the estuarine location. Surface sediment samples were collected from each location. Whole body fish samples were composited or analysed individually based on size. The samples were freezedried, cleaned by a modified Smith-Stalling procedure, and the coplanar PCBs and PCDD/Fs were isolated and analysed by HRGC/HRMS. Low levels of PCDD/Fs were found in all samples: 1-3 pg/g TEQ (wet wt) in fish; 1-5 pg/g I-TEQ (dry wt) in bivalves; and from 3-51 pg/g I-TEQ (dry wt) in sediments with variable PCB levels. With few exceptions, only 2,3,7,8-substituted PCDD/Fs were found in fish, whereas bivalves had both 2,3,7,8-substituted and non-2,3,7,8-substituted PCDD/Fs with relatively high levels of total TCDDs compared to total PeCDD or HxCDD. Sediments had a PCDD/F pattern consistent with pentachlorophenol contamination. Comparison of sediments and collocated bivalves did not indicate bioconcentration in PCDD/Fs, but it did reveal a tenfold increase in PCB #77 and #126. Within each sample type, the PCDD/F and PCB congener profiles were consistent across species and locations. Shifts in congener profiles from sediments to bivalves to fish were consistent across locations. From the available data, the influence of the pulp mill, if any, could not be distinguished from the other sources in the region.

Petrusso, P. A. and D. B. Hayes (2001). "Condition of juvenile chinook salmon in the upper Sacramento River, California." California Fish and Game 87: 19-37.

Petzrick, E. P., C. A. Collins, et al. (1996). Currents through the Golden Gate. San Francisco Bay: The Ecosystem. J. T. Hollibaugh. San Francisco, AAAS: 105-121.

Phillips, B. M., B. S. Anderson, et al. (2003). "Causes of sediment toxicity to Mytilus galloprovincialis in San Francisco Bay, california." Archives of Environmental Contamination and Toxicology 45(4): 492-497.
Since the San Francisco Regional Monitoring Program (RMP) sampling began, elutriate samples prepared with sediment from the Grizzly Bay monitoring station have been consistently toxic to bivalve larvae (Mytilus galloprovincialis). An investigation into the cause of toxicity was initiated with a Phase I Toxicity Identification Evaluation (TIE) using bivalve embryos. TIE results and chemical analyses of elutriate samples suggested that divalent metals were responsible for the observed toxicity. Following the initial characterization of trace metals as toxicants, additional TIEs were performed on elutriates prepared from three additional Grizzly Bay samples collected between 1997 and 2001. Additional TIEs included ethylenediamine tetraacetic acid (EDTA) treatments in a sediment-water interface (SWI) exposure system, and the use of a cation exchange column with serial elution of sample fractions with hydrochloric acid of increasing normality. EDTA significantly reduced toxicity in overlying water in the SWI system. The cation exchange column reduced both toxicity and concentrations of trace metals, and serial elution of the column added back both toxicity and specific metals contained in individual acid fractions. Chemical analyses of three elutriate samples demonstrated copper concentrations were within the range toxic to bivalves. Results of Phase I TIEs, additional Phase II treatments, SWI exposures, and metals analyses indicate the potential for metal toxicity in sediments from this estuarine site. When combined with the results of standard TIE methods, a solid-phase cation extraction and elution approach identified copper as the most probable cause of toxicity.

Phillips, D. J. H., and R.B. Spies (1988). "Chlorinated hydrocarbons in the San Francisco estuarine ecosystem." Marine Pollution Bulletin 19(9): 445-453.

Data on chlorinated hydrocarbons (organochlorine pesticides and PCBs) in the San Francisco Bay and Delta, and its upstream catchment, are reviewed. Data on these contaminants in sediments and biota (mainly bivalve molluscs and teleosts) of the estuary present a consistent picture of contamination of this ecosystem. While many different organochlorines are measurable in the estuary, and some exist at elevated concentrations compared to control or more pristine areas, very little is known of their biological effects. PCBs are particularly widespread in the Bay and Delta, and it appears probable that these compounds at least are exerting detrimental impacts on some organisms. Further investigations of such effects are required if the biological resources of the estuary are to be adequately protected.

Phillis, C., P. Weber, and L. Ingram (2010). Life history diversity within spring-run Chinook salmon populations. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Degradation and removal of habitat often impacts population and life-history diversity non-randomly. For instance, the Sacramento River has experienced a non-random loss of Chinook salmon populations' run timing and rearing strategies due to damming of upstream spawning grounds. In particular, spring-run populations that historically exhibited both a short (3-6 months; ocean-type) and long (10-15 months; stream-type) juvenile freshwater rearing strategy have been either extirpated or are federally listed as threatened under the ESA. Here we examine life-history diversity (i.e. freshwater rearing duration) in the three remaining independent spring-run populations (Mill, Deer, and Butte Creeks) and a fourth population, Clear Creek, which has recently been colonized following removal of a dam. To achieve this we have utilized otolith microchemical methods, specifically Sr isotopes, applied to adult spawners to retrospectively measure temporal and spatial patterns of freshwater residence during the juvenile life stage. We analyzed over 100 otoliths from 2007 spawning adults collected from our four study populations. Residence time in natal streams after first feeding ranged from <2 to 8 months, with most leaving either before 100 days or after 180. Juveniles spent very little time in the Delta (<45 days), even though this is often assumed to be an important rearing habitat. Total time to ocean entry ranged from 2 to 11 months, however >70% of individuals spent 6 months or less in the freshwater system. The current dominant populations in the Sacramento are fall run which only rarely exhibit stream-type behavior. This represents a shift from historical conditions; stream-type populations (i.e., spring and winter run) were prevalent in the Sacramento system before dams removed much of the headwaters habitat. As dams are removed and new habitat is made available, plasticity of these populations and life-histories will determine necessity and degree of management intervention to ensure colonization success.

Phillis, C. C., D. J. Ostrach, et al. (2011). "Evaluating otolith Sr/Ca as a tool for reconstructing estuarine habitat use." Canadian Journal of Fisheries and Aquatic Sciences 68(2): 360-373.

Pilon, V. L. (2006). "Sources and composition of particulate organic matter in the Sacramento-San Joaquin River Delta, California." Dissertation Abstracts International Part B: Science and Engineering 67(1): 154.

Determining organic matter sources and their availability to higher organisms is essential to better understanding the link between organic matter (OM) dynamics and secondary production, particularly in highly-disturbed river- delta systems. The San Francisco Bay and its associated Delta, is one of the most modified aquatic systems, and is the focus of an ongoing restoration effort. Particulate organic matter (POM) and surficial sediments were collected in the Sacramento-San Joaquin River Delta, CA to document temporal and spatial variations in biochemical, (total protein, carbohydrate and lipid), lipid biomarker, and total hydrolysable amino acid (THAA) composition. Sources, composition and nutritional quality of OM was assessed at ten sites representing diverse sub-habitats including each of the two major rivers, rehabilitated shallow-water, open water and natural marsh habitats. Biochemical and biomarker results showed that terrigenous OM and phytoplankton were the primary sources of POM in the Sacramento and San Joaquin

Rivers. On average, the Sacramento River exhibited lower quality POM than the San Joaquin River, due to lower contributions from phytoplankton. Winter periods were characterized by increased delivery of highly degraded, low-quality POM, resulting from higher freshwater flows. In contrast, low flow periods were characterized by phytoplankton blooms and higher-quality POM, particularly in the San Joaquin River during summer. Phytoplankton, submerged macrophytes and terrigenous OM were the dominant sources in SPM and sediments at all shallow-water sites, but to differing degrees. Between-site differences are likely due to variations in the frequency and size of phytoplankton and macrophyte blooms, hydrodynamics and grazing pressures. Shallow-water sites exhibited higher concentrations of biomarkers representing phytoplankton/algal sources than river sites, indicating POM of higher nutritional quality. THAA-based degradation indices (DI) were used to characterize habitats in terms of organic matter degradation state. di indicated that shallow-water habitats were characterized by less degraded POM than river sites, corroborating lipid biomarker analyses. This study demonstrates the value of using a multiple biomarker approach in complex systems such as the Delta. This approach, incorporated into a larger study of the system's biology, hydrology and chemistry provides a useful strategy for addressing management issues in complex deltaic-estuarine systems.

Pisor, R. (2010). The Lathrop Urban Drainage Study: Preliminary results. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Urban development in the Sacramento- San Joaquin River Delta has converted agricultural land into urban communities. This has resulted in an increase in impervious cover which translates to higher flows of runoff with high concentrations of contaminants flowing directly to the rivers and sloughs. The focus of this study is on Lathrop, a small community in the south delta. Because Lathrop is small, we will be able to assess current water quality conditions and be able to monitor changes in this community as it continues to grow. By doing this, we will be able to use Lathrop as a model for other small communities that are growing in the delta. Sampling is conducted during storm events, taken in Lathrop’s pumping stations which pump Lathrop’s stormwater directly to the San Joaquin River, and on the San Joaquin River above and below discharge points. Analysis of the data is focused on environmental and drinking water quality constituents of concern. This poster focuses on the organic carbon and nutrient results from the first season of the study. Total organic carbon concentrations ranged from 2.7 mg/L to 13.4 mg/L, ammonia concentrations ranged from being not detected to 0.44 mg/L and total nitrogen concentrations ranged from 1.05 mg/L to 7.0 mg/L. There were no significant effects from Lathrop’s stormwater discharge to the river. Statement of Relevance: Results from this study will provide a well grounded understanding of how urban growth of cities like Lathrop affects the Bay-Delta’s water quality. This information is vital for developing well informed policy decisions about water quality in the delta.

Pittman, S., and G. Matthews (2010). Sediment transport issues in stream restoration -- 12 years of geomorphic monitoring in lower Clear Creek. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Clear Creek below Whiskeytown Dam has endured 46 years of flow and sediment impairment and the historic geomorphic impacts of gold dredging and gravel mining. Critical flow and sediment issues in Clear Creek include: incomplete routing of coarse sediment, channel armoring, fine sediment delivery, incision to bedrock, simplified channel form and reduced alluvial function. Highly impaired geomorphic function threatens many species of concern including several anadromous salmonid species. Restoration strategies to address these impacts include: pulse flows; channel realignment; floodplain lowering and gravel injection. Twelve years of geomorphic monitoring were used to evaluate the effectiveness of these strategies. Sediment sampling stations were used to develop sediment budgets; repeat topographic and longitudinal surveys to track channel form; particle size analyses to monitor bed texture and bed mobility studies to predict alluvial function. Gravel injection and channel/floodplain modification have restored up to 46% of channel, increasing the areal extent of spawning gravel by over 500% in one two-mile reach. Floodplain and channel restoration projects have increased the frequency of overbank flows,

increased the deposition of silts on floodplains and reduced incision to bedrock and lowered thresholds of bed mobility. Following recent wildfires and subsequent management activities, tributary delivery of fine sediment has dramatically increased. Bulk sample analyses reveal increases in fine sediment that degrade the quality of injected spawning gravels. Tracer gravel studies below gravel injections indicate a reduction in the critical shear stress required to previously-armored mobilize riffles. Measured annual bedload discharges ranged from 392 to over 6,800 tons/yr and indicated complete routing through restoration areas. Understanding the relative role of various sediment sources and rates of transport is paramount to making informed choices regarding gravel additions and planning restoration designs in Clear Creek. Restoration planning must shift to include upslope actions to promote the continued success of mainstem projects.

Poage, V. (2004). Why we do a "post-VAMP shoulder" for delta smelt. IEP Newsletter. 17: 6.

Pondell, C., E. Canuel, and P. Louchouarn (2010). Sources of organic carbon to reservoirs impounded by dams using Englebright Lake as a model system. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Recent studies of sediment and total organic carbon in sediment cores collected from the Sacramento-San Joaquin River Delta document decreasing rates of accumulation since the 1970’s. It has been suggested that water diversion programs, specifically accumulation behind dams, might account for the reduction in sediment concentrations in the Sacramento-San Joaquin River Delta. This study analyzes sediments collected by the USGS in 2002 from behind Englebright Dam on the Yuba River in the Sacramento River watershed for organic carbon content and carbon characterization to determine how the construction of dams has altered the sources of organic carbon to Englebright Lake, how carbon accumulates in this reservoir as well as how changes in upstream tributaries influence the organic carbon signatures over time. Sediments are analyzed using multiple tracers, including lignin biomarkers and stable carbon isotopes, and focusing on shifts in the sources of organic carbon to Englebright Lake, specifically concentrating on variations between terrestrial and aquatic sources. A general trend is observed in these tracers indicating increasing inputs from terrestrial sources to the reservoir since the completion of the Englebright Dam. Sudden shifts in these tracers correspond to periods of high discharge, including large flood events. By utilizing multiple tracers, this study documents how the sources of organic matter to Englebright Lake have changed following dam construction. Changes in organic matter composition are related to variations in land-use practices and climate events with the intention of drawing inferences about the impact of climatic and anthropogenic changes on watersheds in larger, more complex ecosystems like that of the Sacramento-San Joaquin River Delta.

Poulton, V. K., J. R. Lovvorn, et al. (2002). "Clam density and scaup feeding behavior in San Pablo Bay, California." Condor 104(3): 518-527.
San Pablo Bay, in northern San Francisco Bay, California, is an important wintering area for Greater (Aythya marila) and Lesser Scaup (A. affinis). We investigated variation in foraging behavior of scaup among five sites in San Pablo Bay, and whether such variation was related to densities of their main potential prey, the clams Potamocorbula amurensis and Macoma balthica. Time-activity budgets showed that scaup spent most of their time sleeping at some sites, and both sleeping and feeding at other sites, with females feeding more than males. In the first half of the observation period (12 January-5 February 2000), percent time spent feeding increased with increasing density of P. amurensis, but decreased with increasing density of M. balthica (diet studies have shown that scaup ate mostly P. amurensis and little or no M. balthica). Densities of M. balthica stayed about the same between fall and spring benthic samples, while densities of P. amurensis declined dramatically at most sites. In the second half of the observation period (7 February-3 March 2000), percent time feeding was no longer strongly related to P. amurensis densities, and dive durations increased by 14%. These changes probably reflected declines of P. amurensis, perhaps as affected by scaup predation. The large area of potential feeding habitat, and alternative prey elsewhere in the

estuary, might have resulted in the low correlations between scaup behavior and prey densities in San Pablo Bay. These low correlations made it difficult to identify specific areas of prey concentrations important to scaup.

Poulton, V. K., J. R. Lovvorn, et al. (2004). "Spatial and overwinter changes in clam populations of San Pablo Bay, a semiarid estuary with highly variable freshwater inflow." Estuarine, Coastal and Shelf Science 59(3): 459-473.
In many estuaries worldwide, climate trends together with human diversion of fresh water have dramatically impacted the benthos. Such impacts have sometimes been complicated by exotic species, whose invasion and persistence can be mediated by wide variations in freshwater inflow. Monitoring such changes usually involves periodic samples at a few sites; but sampling that does not recognize variation at a range of spatial and seasonal scales may not reveal important benthic trends. San Pablo Bay, in northern San Francisco Bay, has extreme fluctuations in freshwater inflow. This bay also experienced a major benthic change with introduction of the Asian clam (Potamocorbula amurensis) in 1986. This species initially displaced the former community, but later appeared to vary in abundance depending on site and freshwater inflow. To investigate such patterns and provide guidelines for research and monitoring, we took 1746 core samples at six sites around San Pablo Bay from 19 October to 17 December 1999 and from 6 March to 19 April 2000. Most biomass consisted of the clams P. amurensis, Macoma balthica and Mya arenaria. Potamocorbula amurensis dominated the benthos at most sites in the fall and recruited a new cohort during winter, while there was weak recruitment in M. balthica and none in M. arenaria. At most but not all sites, densities of P. amurensis and M. arenaria declined dramatically over winter while M. balthica declined only slightly. The dominant clams had patch diameters > 5 m at most but not all sites, and some showed inconsistent patch structure at scales of 100-1400 m. In this semiarid estuary with highly variable freshwater inflow, samples for research and monitoring should include multiple sites and seasons, and samples within sites should be greater than or equal to5 m apart to account for between-patch variation. Species abundance in winter 1999-2000 appeared to be affected by high freshwater inflows in 1997-1999, while spatial patterns were probably most affected by post-settlement dispersal and mortality. (C) 2003 Elsevier Ltd. All rights reserved.

Powell, T. M., J.E. Cloern, and L.M. Huzzey (1989). "Spatial and temporal variability in South San Francisco Bay (USA). I. Horizontal distributions of salinity, suspended sediments, and phytoplankton biomass and productivity." Estuarine, Coastal and Shelf Science 28(6): 583-597.
The horizontal pattern of mesoscale (1–4 km) variability in salinity was a poor predictor of mesoscale patterns in chlorophyll a, suspended particulate matter, and daily primary productivity in the South San Francisco Bay estuary during spring 1987. The tidally-averaged salinity distribution varied over weekly time scales, reflecting inputs of freshwater as well as transport processes. Spatial distributions of the other quantities also varied weekly, but not in concert with the salt field. Spatial patterns of phytoplankton biomass (chlorophyll a) deviated from the salinity patterns, largely reflecting in situ production of phytoplankton biomass during the spring bloom. The tidally-averaged distribution of suspended particulate matter (SPM) was highly dynamic and responded to (1) the riverine input of suspended sediment during a freshet, (2) neap-spring variations in tidally-driven resuspension, and (3) resuspension in shallows following a period of wind mixing. Two-dimensional distributions of primary productivity P′, derived from maps of biomass and turbidity (SPM), also varied weekly, but the spatial variability of P′ was only about half that of SPM and chlorophyll. Since the magnitude and patterns of spatial variability differ among nonconservative quantities, at least in part because of local sources and sinks, we conclude that the spatial distributions of nonconservative quantities cannot be predicted from distributions of conservative tracers, such as salinity.

Presser, T. S., and H.M. Ohlendorf (1987). "Biogeochemical cycling of selenium in the San Joaquin Valley California, USA." Environmental Management 11(6): 805-821.
Subsurface agricultural drainage waters from western San Joaquin Valley, California, were found to contain elevated concentrations of the element selenium in the form of selenate. In 1978, these drainage waters began to replace previous input

to Kesterson Reservoir, a pond system within Kesterson National Wildlife Refuge; this substitution was completed by 1982. In the 1983 nesting season, unusual rates of deformity and death in embryos and hatchlings of wild aquatic birds (up to 64% of eared grebe and American coot nests) occurred at the refuge and were attributed to selenium toxicosis. Features necessary for contamination to have taken place included geologic setting, climate, soil type, availability of imported irrigation water, type of irrigation, and the unique chemical properties of selenium. The mechanisms of biogeochemical cycling raise questions about other ecosystems and human exposure.

Presser, T. S., M.A. Sylvester, and W.H. Low (1994). "Bioaccumulation of selenium from natural geologic sources in western states and its potential consequences." Environmental Management 18(3): 423-436.
        Ecological impacts of water-quality problems have developed in the western United States resulting from the disposal of seleniferous agricultural wastewater in wetland areas. Overt effects of selenium toxicosis occurred at five areas where deformities of wild aquatic birds were similar to those first observed at Kesterson National Wildlife Refuge in the west-central San Joaquin Valley of California. These areas are: Tulare Lake Bed Area, California, Middle Green River Basin, Utah, Kendrick Reclamation Project Area, Wyoming, Sun River Basin, Montana, and Stillwater Wildlife Management Area, Nevada. Potential for ecological damage is indicated at six more sites in Oregon, Colorado, the Colorado/Kansas border, and South Dakota out of 16 areas in 11 states where biological tissue data were collected. This conclusion is based on the fact that selenium bioaccumulated in bird livers to median levels that had exceeded or were in the range associated with adverse reproductive effects. Selenium concentrations in samples of fish and bird eggs support these conclusions at a majority of these areas. Reason for concern is also given for the lower Colorado River Valley, although this is not exclusively a conclusion from these reconnaissance data. Biogeochemical conditions and the extent of selenium contamination of water, bottom sediment, and biota from which this assessment was made are given here. In a companion paper, the biogeochemical pathway postulated for selenium contamination to take place from natural geologic sources to aquatic wildlife is defined.

Presser, T. S. (1994). "The Kesterson effect." Environmental Management 18(3): 437-454.
        Hypothesized to be derived from Cretaceous marine sedimentary rocks, selenium contamination of the Kesterson National Wildlife Refuge is traced through irrigation drainage to the source bedrock of the California Coast Ranges. This biogeochemical pathway of selenium is defined here as the ''Kesterson effect.'' At the refuge ponds, this effect culminated in 1983 in a 64% rate of deformity and death of embryos and hatchlings of wild aquatic birds. From the previous companion paper on irrigation drainage, the Kesterson effect has been implicated in nine of 11 reconnaissance areas studied in the western United States. Deformities have resulted in at least five of these sites. Climatic, geologic, hydrologic, and soil conditions in these reconnaissance areas are similar to those in the area surrounding Kesterson National Wildlife Refuge in the west-central San Joaquin Valley of California, In California, selenium, as selenate, was ultimately found weathered with sulfur from marine sources in soluble sodium and magnesium sulfate salts, which are concentrated by evaporation on farmland soils. The Se, mobilized by irrigation drainage, is bioaccumulated to toxic levels in refuge wetland ponds that are located mainly in hydrologically closed basins and thus act as concentrating disposal points. The depositional environment of the ponds may be similar to that of the nutrient-rich continental shelf edge and slope in which Cretaceous, Eocene, and Miocene sediments found to be seleniferous in the California Coast Ranges were deposited. Bioaccumulation may be therefore a primary mechanism of selenium enrichment in ancient sediments in addition to that of the formerly suggested Cretaceous volcanic pathway.

Presser, T. S., and D.Z. Piper (1998). Mass balance approach to selenium cycling through the San Joaquin Valley: From source to river to bay. Books in Soils, Plants, and the Environment; Environmental chemistry of selenium. W. T. Frankenberger, Jr., and R.A. Engberg. New York, NY, Marcel Dekker, Inc.: 153-182.

Surface and ground waters of the Central Valley of California are part of a hydrologic system that makes up a complex ecosystem extending from the riparian wetlands of the Sacrament and San Joaquin Rivers through the San Francisco/Delta Estuary to the Pacific Ocean. Water quality concerns center on elevated selenium and salt concentrations in irrigation drainage water discharged into the waterways of the relatively arid San Joaquin Valley. These waters are made unique by dissolved Se, weathered from marine sedimentary rocks of the Coast Ranges to the west, being ultimately concentrated to toxic levels in aquatic wildlife in the wetlands of the SJV/SJR trough.

Presser, T. S., S.N. Luoma, and E. McNaughton (2010). Management of environmental selenium: Underlying science and quantitative answers. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

An ecosystem-scale selenium (Se) model for the Bay-Delta addresses the needs of the Ecosystem Restoration Program and the U.S. Environmental Protection Agency for a biologically-based protocol to evaluate Se risk to fish and wildlife and to systematically quantify each of the processes that link source inputs of Se to toxicity. Five interconnected modules depict essential aspects of hydrology, biogeochemistry, biology, ecology, and ecotoxicology that are important to conceptualizing and quantifying how Se is processed from water through diet to predators and its effects on ecosystems. Quantitative forecasts of the ecological effects of Se on aquatic food webs important to the Bay-Delta are developed through the use of 1) salinity-specific partitioning factors to quantify the effects of dissolved speciation and phase transformation; 2) dietary biodynamics to quantify food web bioaccumulation; 3) seasonal life-cycles of predator species to illustrate exposure; and 4) effect guidelines for fish and birds to set model targets. Submodels depict Sources and Hydrology; Model Processes and Parameters; Food Webs; Seasonal Cycles; Ecotoxicology and Effects; and Human Health. Model sensitivities can be illustrated by varying exposure scenarios, thus facilitating its use for site-specific Se risk assessments and evaluation of the implications of restoration alternatives. Results of modeling scenarios show the dependence of allowable dissolved Se concentrations on site-specific food webs of the estuary and verify that the predicted ranges are realistic in terms of Se concentrations observed within the estuary during the recent past. Choices to initiate modeling would derive from specific questions that arise in planning and implementing restoration actions. The Se database and monitoring program need to be modernized to ensure that predictions using available data would be relevant to today’s estuary. Ecosystem-scale Se modeling offers a major step forward by formalizing the knowledge necessary to understand the basis of Se management decisions for the Bay-Delta.

Presser, T. S. and S. N. Luoma (2006). Forecasting selenium discharges to the San Francisco Bay-Delta Estuary: Ecological effects of a proposed San Luis Drain extension. U.S. Geological Survey Professional Paper 1646: 196 p.

Prest, H. F., W.M. Jarman, S.A. Burns, T. Weismueller, M. Martin, and J.N. Huckins (1992). "Passive water sampling via semipermeable membrane devices (SPMDS) in concert with bivalves in the Sacramento-San Joaquin River Delta." Chemosphere 25(12): 1811-1823.

Freshwater clams (Corbicula fluminea) and the Huckins et al. (1) semi-permeable membrane sampling device (SPMD) were simultaneously deployed at three sites on the Sacramento and San Joaquin rivers in 1990. Both clams and the SPMDs were analyzed for sequestered pesticides and polychlorinated biphenyls (PCBs) by gas chromatography with electron capture detection (GC/ECD). Polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs) and non-ortho PCBs were quantified by high resolution mass spectrometry (MS). In general, levels of organochlorine compounds were approximately 1.6 times higher in clams on a wet weight basis than in the SPMDs, and trends in accumulation were similar except where biofouling of the SPMD membranes decreased uptake rates. Comparisons between the normalized, average levels of PCDDs accumulated showed that while octachlorodibenzo-p-dioxin (OCDD) was most prevalent in both clams and SPMDs, much higher levels of 2,3,7,8 TCDD were found in the SPMDs than in the clams; 2,3,7,8 TCDD was 32% of the profile relative to the OCDD level for the SPMDs and <1% of the clam OCDD level. PCB levels showed the clams primarily accumulated hexachlorinated PCBs while the pentachlorinated and tetrachlorinated congeners were higher in the SPMDs. Differences in profiles for homologous series among the PCBs reveal that some congeners, especially those with 2,4,5 substitution, are more likely to bioaccumulate than those with lower chlorination or adjacent unsubstituted sites. GC/MS chromatograms indicate the SPMDs also sequestered several polyaromatic hydrocarbons. GC/ECD chromatograms indicate the presence of several unidentified, early eluting compounds in the SPMDs.

Purkerson, D. G., M. A. Doblin, et al. (2003). "Selenium in San Francisco Bay zooplankton: Potential effects of hydrodynamics and food web interactions." Estuaries 26: 956-969.
The potential toxicity of elevated selenium (Se) concentrations in aquatic ecosystems has stimulated efforts to measure Se concentrations in benthos, nekton, and waterfowl in San Francisco Bay (SF Bay). In September 1998, we initiated a 14 mo field study to determine the concentration of Se in SF Bay zooplankton, which play a major role in the Bay food web, but which have not previously been studied with respect to Se. Monthly vertical plankton tows were collected at several stations throughout SF Bay, and zooplankton were separated into two operationally defined size classes for Se analyses: 73-2,000 mum, and greater than or equal to2,000 mum. Selenium values ranged 1.02-6.07 mug Se g(-1) dry weight. No spatial differences in zooplankton Se concentrations were found. However, there were inter- and intra-annual differences. Zooplankton Se concentrations were enriched in the North Bay in Fall 1999 when compared to other seasons and locations within and outside SF Bay. The abundance and biovolume of the zooplankton community varied spatially between stations, but not seasonally within each station. Smaller herbivorous-omnivorous zooplankton had higher Se concentrations than larger omnivorous-carnivorous zooplankton. Selenium concentrations in zooplankton were negatively correlated with the proportion of total copepod biovolume comprising the large carnivorous copepod Tortanus dextrilobatus, but positively correlated with the proportion of copepod biovolume comprising smaller copepods of the family Oithonidae, suggesting an important role of trophic level and size in regulating zooplankton Se concentrations.

Rabidoux, A., C. Bowles, and C. Campbell (2010). Assessing the potential restoration impacts to local water users in the Cache Slough Complex: A modeling approach. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The Cache Slough Complex is located in the northwest tidal fringe of the Sacramento – San Joaquin Delta. The Complex is one of the last areas of the Delta where both tidal marsh areas exist and Pelagic Organism species such as delta smelt can be found. There is substantial interest by federal, state, and local agencies to further restore tidal marsh habitat in this area. One possible negative product of tidal marsh creation is the production of dissolved organic carbon (DOC), which can be problematic for municipal water users. In the Cache Slough Complex, the main municipal project is the North Bay Aqueduct (NBA) which serves over 400,000 people in Napa and Solano counties. With the likely creation of substantial wetlands in the Complex, local water agencies are concerned with increases in DOC, which could impact public health, lead to increased regulatory action, and increased water treatment costs. To begin to address these questions cbec, inc., eco engineering was hired to develop a 2-dimensional hydrodynamic model of the entire Cache Slough Complex. A series of restoration scenarios were then determined based upon old reports, current policy discussion with the Bay Delta Conservation Plan, and local interest. A total of six scenarios were developed, which included scenarios representing the restoration of Prospect Island, Lower and Upper Egbert Tract, two scenarios at Hastings Tract, and restoration along Peter’s Pocket and Moore Tract. Computational tracers were applied at each levee breech to represent sources of DOC and to study the fate and transport of the tracer through the Complex. Each scenario was modeled for 10-days and a comprehensive scenario was modeled for 30-days. The model results show that proximity to the NBA is the single biggest factor. Additionally, local diversions such as the NBA and agricultural diversions substantially influence the hydrodynamics. The model results also show that likely restoration scenarios a substantial distance from the NBA, such as Prospect Island, will not likely impact water quality at the NBA.

Radovich, J. (1963). "Effect of ocean temperature on the seaward movements of striped bass, Roccus saxatilis, on the Pacific coast." California Fish and Game 49: 191-205.

Rahimi-Ardabily, S. (2010). Sacramento River Flows, Water Years 2008 and 2009. IEP Newsletter. 23: 2.

Ralston, D. K., W. R. Geyer, et al. (2008). "Subtidal Salinity and Velocity in the Hudson River Estuary: Observations and Modeling." Journal of Physical Oceanography 38(4): 753-770.
A tidally and cross-sectionally averaged model based on the temporal evolution of the quasi-steady Hansen and Rattray equations is applied to simulate the salinity distribution and vertical exchange flow along the Hudson River estuary. The model achieves high skill at hindcasting salinity and residual velocity variation during a 110-day period in 2004 covering a wide range of river discharges and tidal forcing. The approach is based on an existing model framework that has been modified to improve model skill relative to observations. The external forcing has been modified to capture meteorological time-scale variability in salinity, stratification, and residual velocity due to sea level fluctuations at the open boundary and along-estuary wind stress. To reflect changes in vertical mixing due to stratification, the vertical mixing coefficients have been modified to use the bottom boundary layer height rather than the water depth as an effective mixing length scale. The boundary layer parameterization depends on the tidal amplitude and the local baroclinic pressure gradient through the longitudinal Richardson number, and improves the model response to spring-neap variability in tidal amplitude during periods of high river discharge. Finally, steady-state model solutions are evaluated for both the Hudson River and northern San Francisco Bay over a range of forcing conditions. Agreement between the model and scaling of equilibrium salinity intrusions lends confidence that the approach is transferable to other estuaries, despite significant differences in bathymetry. Discrepancies between the model results and observations at high river discharge are indicative of limits at which the formulation begins to fail, and where an alternative approach that captures two-layer dynamics would be more appropriate.

Ralston, D. K. and M. T. Stacey (2005). "Stratification and turbulence in subtidal channels through intertidal mudflats." Journal of Geophysical Research-Oceans 110(C8).
[1] Field observations in San Francisco Bay of subtidal channels that drain through intertidal mudflats indicate that substantial periodic stratification develops in very shallow flows with distinct asymmetries between flood and ebb conditions. The greatest variability in salinity and stratification occurs during the wet winter months. Very strong longitudinal salinity gradients develop across the intertidal zone, between salty subtidal water and fresher water draining into the marsh upstream. Tidal straining of the longitudinal gradient creates the periodic stratification, stratifying through ebbs and destratifying through floods. The stratification can be very strong in very shallow flows, with N-2 > 0.1 s(-2) in about 0.5 m water depth. Analysis of the data with dimensionless numbers shows that at times the stratification is strong enough to suppress turbulence and mixing. The asymmetry in stratification between ebbs and floods results in asymmetries in eddy viscosity and eddy diffusivity, with lower values during the stratified ebbs. Because of the intertidal elevation of the system, the strong longitudinal salinity gradient is regenerated each time the mudflats and marsh drain. The system approaches a tidally periodic steady state where the flow dynamics are dominated by the sharp front of salty water that advects into the intertidal zone on the rising tide and exits the system by each lower low water. The field data are supported by a numerical model with simple mudflat/ channel bathymetry. Both the field and numerical work indicate that the shallow, low energy flows in mudflat channels transition between strongly stratified suppressed turbulence and relatively unstratified active turbulence each tidal cycle.

Ralston, D. K. and M. T. Stacey (2006). "Shear and turbulence production across subtidal channels." Journal of Marine Research 64(1): 147-171.

In intertidal regions with subtidal channels, effects of bathymetry on overlying flow vary greatly with tidal stage. Around low water when mudflats and marsh are exposed, flow is constrained to channels, but when water depths are greater, tidal forcing may not necessarily be aligned with meandering channel axes. Flow across the channel can generate strong shear and turbulence at the elevation of the channel banks and can significantly increase turbulent energy in the middle of the water column. Field observations in a mudfiat channel of San Francisco Bay indicate that cross-channel shear regularly occurs there early in ebb tides. With increased freshwater flow, baroclinic forcing can enhance shear by decoupling flow between dense water flooding in the channel and fresher water ebbing above the channel banks. A water column numerical model with k-epsilon turbulence closure is modified to represent the cross-channel shear production. Numerical results with uniform density indicate that turbulence production increases with the angle between the barotropic tidal forcing and the channel axis. When a longitudinal salinity gradient is imposed, cross-channel shear production contributes to breakdown of periodic stratification. Turbulence produced at the channel banks locally exceeds dissipation, and the excess energy is either lost to buoyancy or diffuses vertically to lower energy regions near the surface and near the bed. The balance among shear production, buoyancy production, and diffusion of turbulence depends on the flow angle and the strength of the longitudinal salinity gradient.

Ralston, D. K. and M. T. Stacey (2007). "Tidal and meteorological forcing of sediment transport in tributary mudflat channels." Continental Shelf Research 27(10-11): 1510-1527.
Field observations of flow and sediment transport in a tributary channel through intertidal mudflats indicate that suspended sediment was closely linked to advection and dispersion of a tidal salinity front. During calm weather when tidal forcing was dominant, high concentrations of suspended sediment advected up the mudflat channel in the narrow region between salty water from San Francisco Bay and much fresher runoff from the small local watershed. Salinity and suspended sediment dispersed at similar rates through each tidal inundation, such that during receding ebbs the sediment pulse had spread spatially and maximum concentrations had decreased. Net sediment transport was moderately onshore during the calm weather, as asymmetries in stratification due to tidal straining of the salinity front enhanced deposition, particularly during weaker neap tidal forcing. Sediment transport by tidal forcing was periodically altered by winter storms. During storms, strong winds from the south generated wind waves and temporarily increased suspended sediment concentrations. Increased discharge down the tributary channels due to precipitation had more lasting impact on sediment transport, supplying both buoyancy and fine sediment to the system. Net sediment transport depended on the balance between calm weather tidal forcing and perturbations by episodic storms. Net transport in the tributary channel was generally offshore during storms and during calm weather spring tides, and onshore during calm weather neap tides.

Raquel, P. F. (1986). "Juvenile blue catfish Ictalurus furcatus in the Sacramento-San Joaquin Delta of California, USA." California Fish and Game 72(3): 186-187.

Raquel, P. F. (1989). Effects of handling and trucking on chinook salmon, striped bass, American shad, steelhead trout, threadfin shad, and white catfish salvaged at the John E. Skinner Delta Fish Protective Facility. Sacramento CA, Interagency Ecological Program for the San Francisco Bay/Delta Estuary: 56 pp.

Rattray, M., Jr. and C. B. Officer (1979). "Distribution of a non-conservative constituent in an estuary with application to the numerical simulation of dissolved silica in the San Francisco Bay." Estuarine and Coastal Marine Science 8(5): 489-494.
A simplified relation between the distribution of a non-conservative quantity and the distribution of salinity in an estuary is developed analytically from the conservation equations. The relation is tested against a numerical simulation of the same problem using a two-dimensional gravitational circulation model.

Redler, Y., R. del Rosario, and D. Swank (2010). Use of the Sacramento/San Joaquin estuary by fry-sized emigrants: Implications for life history diversity and conservation of Central Valley fall-run Chinook salmon. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The four species of Chinook salmon in California’s Central Valley coexist due to spatial and temporal reproductive isolation and staggered emigration windows. Within a run, a wide range of juvenile size and timing at emigration contributes to population resiliency during environmental fluctuations. Of the Central Valley Chinook salmon, the fall run is the most abundant, has the longest emigration season, and the largest geographic distribution. During the last 15 years, we observed a decline in numbers of fall run exiting the Delta as fry during the early part of the population’s emigration window, January through March. We analyzed monitoring data from the lower Sacramento River, the western Delta at Chipps Island, and San Pablo Bay from 1995-2009, to compare the temporal distribution of fry entering and exiting the Delta over the years. Long-term monitoring data show that fry-size (<70mm FL) fall run Chinook salmon historically exited the Delta at Chipps Island from January through March. This was followed by an influx of smolt-sized fish (>70 mm FL) (predominantly of hatchery origin) in April. Starting in 2002, fall run fry were observed exiting at Chipps Island only in March. Since 2007, no fall run fry have been captured at Chipps Island. Two notable events occurred that may have compromised fall run fry emigrants in recent years: 1) The predominantly wet years of 1995-2000 turned to predominantly dry years beginning in 2001, and 2) Delta export to Delta inflow ratios increased in drier water years resulting in less flow for rearing and migration. We considered potential biases due to changes in sampling gear as well as changes in hydrology. We examined factors that make the estuary suitable for fry rearing, and what modifications in water management or habitat restoration might be useful in ensuring continuation of this juvenile life history.

Reece, C. K., and T.R. Sommer. (2008). Yolo Bypass Study Highlights. IEP Newsletter 21: 10.

Reece, C. K., and T.R. Sommer (2010). Fish communities at the interface of tidal wetlands and seasonal floodplain. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The 24,000 ha Yolo Bypass floodplain drains from the Sacramento River watershed into the north Delta, specifically the tidal Cache Slough Complex. For the past 12 years we have operated a rotary screw trap to examine fish communities at the base of this seasonal floodplain at Liberty Island. Over this period we collected a total of 42 species including federally listed species (delta smelt Hypomesus transpacificus, Chinook salmon Oncorhynchus tshawytscha) and several game species (American shad Alosa sapidissima, striped bass Morone saxatilis, crappie Pomoxis spp.). Like other regions of the estuary, alien fishes comprised a large portion of the individuals in the fish assemblages collected in the Yolo Bypass (73% for screw trap samples). However, we found evidence that the timing of occurrence of native fishes was earlier than alien species, consistent with their life history and data on adult migration patterns. We hypothesize that the Yolo Bypass may especially important to native fish because the inundation of seasonal floodplain typically occurs early in the calendar year, providing access to vast areas of spawning and rearing habitat with an enhanced food web. Moreover, we propose fish and food web production from the seasonal floodplain represent an important energy and biodiversity “subsidy” to the tidal wetlands that it drains into.

Reece, C. K., W. Harrell, and T.R. Sommer (2010).
Fish presence in California’s Yolo Bypass floodplain. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Reed, D., and A. Commagere (2010). BREACH III: Identifying and quantifying the factors influencing elevation change. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The BREACH conceptual model of vegetation threshold processes for flooded islands in the delta indicates the following factors affect elevation of the island

surface: sediment supply, tidal flows, wave energy and vegetative growth. Previous studies of elevation change conducted for BREACH I and BREACH II showed increased sediment accumulation at sites in the northern delta, apparently associated with the influence of flood events on the Yolo Bypass. These studies also identified belowground organic contributions as being an important influence on elevation change in marshes throughout the Delta. In BREACH III, our focus will be on quantifying both the role of vegetative processes (above-ground sediment trapping and belowground biomass accumulation) in driving elevation change and how sediment deposition changes as vegetation colonizes open mudflats. This understanding is crucial to predicting the transition from open intertidal to emergent wetland in breached sites. The initial phase of this study is to characterize the thickness and nature of the sediment being deposited in Liberty Island. In May 2010, 27 shallow cores were taken in eight transects encompassing both exposed and sheltered environments. Sampling focused on open mudflat, marsh edge and interior marsh environments. Where a ‘transition’ marsh with low stem density was present this was also sampled. Cores were partitioned at 5cm intervals and are being analyzed for bulk density and organic matter content. This analysis will also allow the identification of the depth of sediment deposited over the previous agricultural surface. Patterns of sediment deposition among and across the transects will be used to determine the location of long term elevation change monitoring sites, using Rod Surface Elevation Tables (RSET), which will be established in Fall 2010.

Rees, J. T. (1982). "The hydrozoan cladonema in California: A possible introduction from East Asia." Pacific Science 36(4): 439-444.

A hydrozoan of the genus Cladonema, new to the American west coast, is described from specimens taken from a display tank on the Berkeley campus of the University of California. Observations of its life history revealed it to be synonymous with Cladonema uchidai Hirai, 1958, known and described from northern Japan, although its distribution is probably much wider and includes coastal China and the USSR. The species is presumed to be present in San Francisco Bay, a point of introduction for many exotic species, although it is not yet known from the field

Rees, J. T. and L. A. Gershwin (2000). "Non-indigenous hydromedusae in California's upper San Francisco Estuary: life cycles, distribution, and potential environmental impacts." Scientia Marina 64: 73-86.

Two species of hydromedusae, assumed to be native to the Black and Caspian Seas, were routinely collected in Suisun Slough, California, at the Suisun City Marina, during late summer and fall of 1997. Suisun Slough connects directly with Suisun Bay, part of the biologically complex and commercially important upper San Francisco Estuary, and with San Francisco Bay via San Pablo Bay. Maeotias marginata (Modeer 1791), has been previously reported (as M. inexspectata) from the Petaluma River, another tributary entering San Pablo Bay, while an as-yet undetermined species of Moerisia represents a new distributional record far this genus in the eastern Pacific. Morphologies of the adults and immature growth stages of medusae of both species are described. The polyp stages of both species were reared in the laboratory following spawning of adult medusae collected from the field. Both species are apparently representative of the robust and aggressive Black and Caspian Seas brackish water fauna, many species of which have been introduced into estuarine habitats worldwide. The potential of these planktonic predators to alter zooplankton communities and feed directly on larval and juvenile stages of threatened native and commercially valuable estuary fish species are all possible, but remain uninvestigated.

Rein, S. R. (1993). A model of chinook salmon population dynamics, University of California, Berkeley.

Reiter, M., J. Wood, L. Stenzel, G. Page, L. Liu, and C. Hickey (2010). Wintering shorebirds in the San Francisco Bay estuary: population change and future monitoring. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The San Francisco Bay estuary (SF Bay) provides habitat for more migrating and wintering shorebirds than any other coastal wetland on the US Pacific coast south of Alaska and has been designated as a site of hemispheric importance by the

Western Hemisphere Shorebird Reserve Network. Currently there is no annual effort to monitor shorebirds using SF Bay despite ongoing habitat changes in the estuary. Designing an efficient and robust annual shorebird monitoring program for SF Bay is an essential step towards the long-term conservation and management of shorebirds in the Western Hemisphere. As part of a larger project to develop a monitoring program for wintering shorebirds in all of California, we employed data from comprehensive November censuses of SF Bay (1990 – 1992 and 2006 – 2008) to quantify spatial and temporal changes in shorebird populations between time periods and to conduct spatial sampling simulations. We assessed the efficacy of reduced effort surveys (e.g. 50% of comprehensive survey) and several sampling frameworks (e.g. stratified random sampling) to identify changes in shorebird populations in SF Bay that were observed in the high-effort, comprehensive censuses. Our data suggest that, overall, populations of the majority of shorebird species in SF Bay were similar between 1990 – 1992 and 2006 – 2008 with the mean total number of shorebirds counted annually in the two time periods being 342,991 and 344,954, respectively. Our simulations suggested that a 75% reduction in survey effort could provide estimates of population change within 20% of the true change using an appropriately weighted stratified sampling design. Based on this analysis, we propose a statistically robust, logistically feasible, long-term monitoring program for wintering shorebirds in SF Bay to track spatial and temporal population trends and the impact of changing climate and habitat conditions.

Rettinghouse, T. (2009). Fish Conservation and Culture Lab (FCCL), Winter 2009. iEP Newsletter. 22: 1.

Rettinghouse, T. (2010). Fish Conservation and Culture Lab (FCCL), Spring 2010. IEP Newsletter. 23: 3.

Reyes, E. (2010). Watershed process model development for Liberty Island, CA. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The conceptual model developed from from the initial BREACH studies proposed an evolutionary path from subtidal open water, through emergent mudflats to vegetation colonization and ultimately mature marshes. This conceptual model identified different stages in wetland development and articulated the interactions among these factors for intertidal pioneer and mature tule (Schoenoplectus acutus) conditions. In addition to providing habitat and building marsh soil, vegetation colonization is of critical importance in determining channel pattern and the amount of open water within Delta marshes. Our goal is to provide a predictive level of understanding about abiotic and biotic controls on vegetation colonization in restoring wetlands integrating historical and concurrent environmental data with the use of a simulation model to assess wetland features at the landscape scale. We have begun developing this mechanistic process-based ecological watershed model to assess “restoration thresholds” of emerging north delta wetland landscapes. This type of spatial model incorporates location- specific algorithms to allow feedback between the local processes and landscape dynamics. The watershed model for Liberty Island combines physical and biological information at different scales in three modules: hydrodynamic, soil, and macrophyte productivity dynamically coupled via a unit ecosystem model. The model also contains a habitat-switching module that tracks habitat characteristics for each land parcel, such that long-term processes and ecological responses can be examined. We plan to build and use this watershed model to understand hydrologic and geomorphic changes and ecological responses at scales from local to the entire restoration site, and relationships to the adjoining landscape. Our research objective is to build an improved multiple-scale process ecological model for the Liberty Island marshes aimed to understand regional habitat change in long-term basis. Model results could be used to assess how the transport and routing of water and changes in habitat composition influence faunal response within the basin.

Reyes, J. A., C.M. Waggoner, D. Causey, and K.M. Kelley (2010). Indicators of environmental stressors, endocrine disruption, and physiological impacts in wild fish of the San Francisco Bay region. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Prior research in the San Francisco Bay region has demonstrated that resident fish are exposed to a variety of contaminant chemicals, from pesticides to polychlorinated biphenyls (PCBs). In several lines of research, we are beginning to elucidate phenotypic effects in fish related to such exposures and which are indicative of maladaptive consequences to physiology and health. As one example, shiner surfperch sampled from contaminated San Francisco Bay locations exhibit a form of endocrine disruption involving the stress and metabolic hormone, cortisol, which is associated with impairments in physiological performance indices relating to growth and defense. The primary disruption effect, an inability of the fish to activate a normal neuroendocrine response to stress, is significantly correlated with exposures of the fish to certain congeners of polycyclic aromatic hydrocarbons (PAHs) and PCBs. In addition to endocrine disruption, important hepatic proteins exhibit altered expression in association with contaminant exposures. Using proteomics technologies, hepatic biomarkers indicative of detoxification processes (e.g., GST, Cyp1A), catabolic physiology (e.g., gluconeogenic and glycolytic enzymes), and cellular responses (e.g., chaperones) have all been identified in impacted fish. Furthermore, protein expression within the endocrine tissue that synthesizes cortisol (interrenal) is being characterized in studies aimed at elucidating the underlying mechanism(s) of the endocrine-disrupted condition. Altogether, these studies contribute to a multi-factorial analysis in environmentally impacted fish, which is building an increasingly integrative perspective on the health status and physiological performance in the subject animals. Development of broader-based “systems” approaches to determining cause and effect are poised to provide more comprehensive and powerful assessments of environmental quality. (Support in part by Pacific Coast Environmental Conservancy, NOAA-USC Sea Grant Program, and SFEI-RMP for Water Quality in SF Bay).

Reynolds, F. L., T.J. Mills, R. Benthin, and A. Low (1993). Restoring Central Valley streams: A plan for action. Sacramento, CA, California Department of Fish and Game.

Reynolds, P. (2010). Habitat creation along lower Sacramento River levees. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Flood management is a critical issue facing California’s Bay-Delta region. Many of the levees along the lower Sacramento River are experiencing substantial erosion. Levees can have significant impacts on biological resources and fish in particular. Therefore, habitat features are being incorporated into many levee repair designs. H.T. Harvey & Associates was hired by DWR to prepare and implement a monitoring plan to evaluate the habitat features and fish use of several levee repair designs along the lower Sacramento River and to compare habitat features on constructed levees to existing naturalized sites. Naturalized sites chosen typically contained little rip-rap and tended to support well developed wetland and riparian vegetation and often exhibited high loading of Instream Woody Material (IWM). We collected habitat feature data utilizing the methods described in the standardized assessment methodology (SAM) model at 13 levee repair and 8 naturalized sites between river mile 10.7 and 91.9 on the lower Sacramento River. We found habitat developing at all of the repair sites in the form of substantial IWM, moderate aquatic vegetation and initial establishment of overhanging shade. When comparing the repair sites to naturalized sites, the substrate size varied considerably, and the IWM values were similar higher on the bank where winter/spring flows often inundate. However, in lower, more regularly inundated areas, less IWM was present at repair sites than naturalized sites. There was more aquatic vegetation and overhanging shade at the naturalized sites compared to the repair sites. When comparing the different levee designs there were substantial differences in habitat features present. Although the repair sites were generally only 2-3 growing seasons old when our data were collected, the results suggest that the habitat features incorporated into these designs are on a trajectory toward approximating naturalized sites in coming decades.

Rheinheimer, D., S. Ligare, V. Mehta, and J. Viers (2010). Simulating regulated flows in the west slope Sierra Nevada with uniform climate warming of 2, 4, and 6 °C using WEAP21. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

We developed a water management models for the 15 major basins of the west slope Sierra Nevada to better understand how regulated flows might respond to anticipated regional climate warming. The models, built using WEAP21, simulate hydropower, reservoir operations, water supply demand, and some flood control with a weekly time step across a 20-year time horizon. Simulated changes in climate were restricted to increasing air temperature by 2, 4, and 6 °C and maintaining historical patterns of precipitation. Preliminary results demonstrate that flows abstracted for hydropower generation vary by changes in water year type and losses from reservoir evaporation. We discuss how hydropower systems tend to shift abstractions within a year to match alterations in the timing and magnitude in unimpaired runoff to limit annual losses (i.e., generation and revenue) and how evaporation losses from reservoirs change with climate warming. These potential changes in water management will need to be considered when developing long term management strategies for sustaining Sacramento-San Joaquin Delta ecosystems and California water supply.

Ribeiro, F., P. K. Crain, et al. (2004). "Variation in condition factor and growth in young-of-year fishes in floodplain and riverine habitats of the Cosumnes River, California." Hydrobiologia 527(1): 77-84.
Condition factors and growth rates of postlarval (young-of-year) fishes in a Central California river were compared in order to determine the relative importance of floodplain and riverine habitats for rearing. Sampling took place between April and June of 2001 and 2002 in the lower Cosumnes River and its floodplain. Sacramento splittail showed higher condition and length increment in floodplain habitats than in riverine habitats. Sacramento suckers showed differences in condition between sites, but suckers from the floodplain had lower weight increments than those from the river. The weight increment in Sacramento splittail was not significantly different between habitats. In addition, two alien species, common carp and golden shiner, had similar condition factors and growth rates. This study shows the usefulness of condition factor and growth rate in evaluating the importance of different habitats for early life history stages of fishes.

Rice, A. and B. Tsukimura (2004). "A key to Brachyuran zoea of the San Francisco Bay Estuary." Integrative and Comparative Biology 44(6): 741-741.

Rice, A. and B. Tsukimura (2007). "A key to the identification of brachyuran zoeae of the San Francisco Bay estuary." Journal of Crustacean Biology 27(1): 74-79.
San Francisco Bay and its estuary is a heavily invaded region due to organisms arriving in ballast water and on fouled ships, as well as with the intentional release of non-native species. Recent crab invasions rendered previous means to identify crab larvae unusable. We provide an illustrated dichotomous key with descriptions of stage I zoeae, and to facilitate identification use external characters that remain definitive through all zoeal stages. Crab zoeae included in this key are as follows: Cancer antennarius, Cancer gracilis, Cancer magister, Cancer productus, Carcinus maenas, Eriocheir sinensis, Hemigrapsus nudus, Hemigrapsus oregonensis, Lophopanopeus bellus, Rhithropanopeus harrisii, Pachygrapsus crassipes, Pyromaia tuberculata, and the family Pinnotheridae. This work aims to provide a tool to aid in the understanding of brachyuran zoeae of the San Francisco Bay and estuary.

Rice, J. and K. Newman (1997). Statistical model for survival of chinook salmon smolts outmigrating through the lower Sacramento-San Joaquin system. Sacramento, Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 59.

Richman, S. E. and J. R. Lovvorn (2004). "Relative foraging value to lesser scaup ducks of native and exotic clams from San Francisco Bay." Ecological Applications 14(4): 1217-1231.
Invasions of exotic invertebrates have greatly altered many aquatic communities, but impacts on the foraging energetics of predators seldom have been assessed. In San Francisco Bay, California (USA), a major community change occurred with introduction of the Asian clam (Potamocorbula amurensis) in 1986. This species now greatly outnumbers the previous clam prey of a variety of sharks, rays,

sturgeon, flatfish, and crabs, as well as several diving duck species for which the bay is the most important wintering area on the U.S. Pacific Coast. P. amurensis also accumulates much higher levels of some contaminants than the formerly dominant prey. Because alteration of the food base or contaminated foods on wintering areas may be factors in the population decline of scaup ducks, effects of this exotic invasion are important to assess. For Lesser Scaup (Aythya affinis), we studied effects of differences in nutrient content, digestibility, crushing resistance of shells, areal density, size, and depth in the sediments on the relative foraging value of exotic P. amurensis vs. the formerly dominant native clam Macoma balthica. P. amurensis, including shells, had higher nitrogen and energy content per clam of the same length class, and higher digestibility of energy, than M. balthica. Gut retention time did not differ between clam species, so their relative profitability for scaup was determined mainly by the intake rate of digestible nutrients during short, costly dives. For scaup foraging ill all aquarium 1.8 m deep, intake rates (number of prey per second) of food items buried in sand-filled trays increased with increasing prey density up to at least 4000 prey/m(2). For items buried 3 cm deep, intake rates did not differ for prey <6 mm long vs. prey 6-12 mm long; however, intake rates were much lower when prey were deeper in the sediments (6 cut vs. 3 cm). In the field, a much higher percentage of P. amurensis were in the length range most commonly eaten by Lesser Scaup (<12 mm), and unlike M. balthica, almost all P. amurensis were in the top 5 cm of sediments where scaup intake rates are highest. In tensometer measurements, shells of P. amurensis were much harder to crush than shells of M. balthica, which might partly offset the apparent energetic advantages of P. amurensis. In many respects, the exotic P. amurensis appears to be a more valuable food than the native M. balthica for Lesser Scaup. However, because P. amurensis accumulates much higher levels of some contaminants, this exotic invasion increases the risk of toxicity to scaup and a range of other benthic predators.

Ridolfi, K., L. Grenier, C. Austin, L. McKee, and J. Davis (2010). Assessing impairment of Tomales Bay due to mercury. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Mercury (Hg) contamination is a key challenge impacting ecosystems in the Bay-Delta region of California. Though Tomales Bay’s relatively localized, recent Hg source and distribution contrasts with the Bay-Delta’s wide range of Hg sources (dominated by legacy mining) and larger spatial distribution, management of the two systems have faced similar challenges and used some of the same methodologies to develop regulatory guidelines. This study offers insights into better understanding and managing the Bay-Delta ecosystem through the example of studying mercury contamination in Tomales Bay. Mercury mining occurred in the 1960s on Walker Creek, a major tributary to Tomales Bay. Since then, storm events transported mercury-laden sediment into Tomales Bay, resulting in a bay-wide fish consumption advisory for sport fish. We focused on risk to birds and wildlife from mercury to supplement existing information on risk to humans. To assess risk to wildlife, we calculated numeric targets based on prey fish following the same methodology used in the Guadalupe River and Delta TMDLs, and collected common species of small prey fish to determine if mercury concentrations in fish exceed these targets. Target prey fish (5-15cm in length) had a mean Hg concentration of 0.05 μg/g ww, meeting the numeric target for protection of piscivorous wildlife. Additionally, we collected sediment and water samples to answer key questions regarding the spatial distribution of total and methylmercury. Since elevated sediment mercury concentrations were confined to the Walker Creek delta (where mining-contaminated sediments accumulate), we conducted a second round of biota sampling in that area on a wider range of bird prey to better assess risk to birds from mercury. The results will be used by the San Francisco Bay Regional Water Quality Control Board to develop a TMDL for mercury in Tomales Bay, and as a baseline for a long term monitoring program.

Ritson, P. I., R.M. Rouse, R.A. Flegal, and S.N. Luoma (1999). "Stable lead isotopic analyses of historic and contemporary lead contamination of San Francisco Bay Estuary." Marine Chemistry 64(1-2): 71-83.
Variations in stable lead isotopic composition (204Pb, 206Pb, 207Pb, 208Pb) in three sediment cores from the San Francisco Bay estuary document temporal changes in sources of lead during the past two centuries. Sediment, with lead from natural geologic sources, and relatively homogeneous lead isotopic compositions are overlain

by sediments whose isotopic compositions indicate change in the sources of lead associated with anthropogenic modification of the estuary. The first perturbations of lead isotopic composition in the cores occur in the late 1800s concordant with the beginning of industrialization around the estuary. Large isotopic shifts, toward lower 206Pb/207Pb, occur after the turn of the century in both Richardson and San Pablo Bays. A similar relationship among lead isotopic compositions and lead concentrations in both Bays suggest contamination from the same source (a lead smelter). The uppermost sediments (post 1980) of all cores also have a relatively homogenous lead isotopic composition distinct from pre-anthropogenic and recent aerosol signatures. Lead isotopic compositions of leachates from fourteen surface sediments and five marsh samples from the estuary were also analyzed. These analyses suggest that the lead isotopic signature identified in the upper horizons of the cores is spatially homogeneous among recently deposited sediments throughout the estuary. Current aerosol lead isotopic compositions [Smith, D.R., Niemeyer, S., Flegal, A.R., 1992. Lead sources to California sea otters: industrial inputs circumvent natural lead biodepletion mechanisms. Environmental Research 57, 163–175] are distinct from the isotopic compositions of the surface sediments, suggesting that the major source of lead is cycling of historically contaminated sediments back through the water column. Both the upper core sediments and surface sediments apparently derive their lead predominantly from sources internal to the estuary. These results support the idea that geochemical cycling of lead between sediments and water accounts for persistently elevated lead concentrations in the water column despite 10-fold reduction of external source inputs to San Francisco Bay.

Rivera-Duarte, I. and A. R. Flegal (1994). "Benthic lead fluxes in San Francisco Bay, California, USA." Geochimica et Cosmochimica Acta 58(15): 3307-3313.
Porewater concentration gradients indicate relatively large benthic fluxes of Pb from sediments in the San Francisco Bay estuary. Gradients in total dissolved (<0.45 mu m) Pb concentrations in sediment porewaters, which range from 0.07-19.2 nM, parallel gradients in ammonia and dissolved Fe in sediment cores from the bay. Corresponding Fickian diffusive fluxes range from 2.6 x 10 super(-9) moles/m super(2)/d to 3.1 x 10 super(-8) moles/m super(2)/d in anoxic surface (<2 cm) sediments along the periphery of the estuary. These indicate the net diffusive benthic flux of Pb from sediments in San Francisco Bay (3-31 moles d super(-1)) is at least an order of magnitude greater than the fluvial input of dissolved Pb to the estuary (0.2 moles d super(-1)) during low flow periods. Moreover, estimates of the total benthic Pb flux, which were based on Hammond et al. (1985) irrigation benthic flux model, are two- to six-fold greater (6-186 moles d super(-1)) than the estimates of diffusive fluxes. Therefore, the total benthic flux of Pb from the bay's sediments may be within an order of magnitude of the total anthropogenic flux of Pb to the San Francisco Bay estuary (965-8,410 moles/d).

Robinson-Nilsen, C., J. Bluso-Demers, C. Strong, J. Ackerman, and S. Demers (2010). Increase of the California gull population in the San Francisco Bay and the impacts on western snowy plovers. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
California Gulls first bred in the San Francisco Bay in 1980, when 12 nests were found on a dry salt pond. In 2009, over 43,000 California Gulls were breeding in the Bay. Meanwhile, the breeding population of the federally threatened Western Snowy Plover in the Bay has remained at approximately 130 individuals, well below the recovery goal of 500 for the region. California Gulls in San Francisco Bay depredate the eggs and chicks of waterbirds, but their impacts on breeding Snowy Plovers are unknown. To determine the extent of gull predation on Snowy Plover nests, we deployed nest cameras in 2009 and 2010 at Eden Landing Ecological Reserve (ELER). We tested the effectiveness of habitat enhancements to reduce predation on plover nests by placing treatment plots (oyster shells) at ELER using a randomized block design. California Gulls accounted for 25% of Snowy Plover nest predators captured on camera. The oyster shell enhancements were successful, with 66% of Snowy Plover nests in the oyster shell plots hatching compared to 50% of nests outside the plots. Only 8% of the nests in the oyster shell plots were depredated compared to 44% of outside the plots. Despite the success of the oyster shell enhancements, the growing California Gull population may threaten the recovery of Snowy Plovers in San Francisco Bay. Over 25,000 California Gulls currently nesting in a former salt pond

(Pond A6) will be displaced when it is restored to tidal marsh under the South Bay Salt Pond Restoration Project. Our results, along with the recent documentation of the first California Gull nest in ELER, where 60% of Snowy Plovers in the Bay nest, suggest that gulls may increase predation on waterbird nests and chicks or encroach on the breeding habitat of other waterbirds once displaced from Pond A6.

Rockriver, A. K. (2004). Vertical Distribution of Larval Delta Smelt and Striped Bass near the Confluence of the Sacramento and San Joaquin Rivers. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 97-108.

The goal of this study was to determine if the vertical distribution of larval delta smelt Hypomesus transpacificus and striped bass Morone saxatilis was affected by tidal stage and diel period. Delta smelt and striped bass have similar early life histories in that their larvae drift downstream from freshwater spawning habitats to brackish water rearing habitats. Little is known on whether the larvae undergo a vertical migration as they move downstream. Conical plankton nets were used to collect larval fishes from the surface, middle, and bottom sections of the main channels of the Sacramento and San Joaquin rivers. Samples were collected over six paired day-night cruises. Approximately 45,000 fish were collected; 82% were striped bass and 2% were delta smelt. More delta smelt were caught at night than during the day, and more at middle depth than surface or bottom. Very few striped bass were found at surface during day; most were caught at middle depth. Both species were fairly dispersed throughout the water column at night. Although striped bass larvae appear to undergo a small surface to middepth migration, this study indicates that larval delta smelt and striped bass do not undergo a mass diel or tidal vertical migration as they drift down the Sacramento and San Joaquin rivers.

Roegner, A., B. Puschner, and A. Khademhosseini (2010). Novel application of microscale aggregate culture of hepatocytes to screen for harmful cyanobacterial bloom toxins. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Microcystins comprise a family of over 80 potent hepatotoxins prevalent in harmful algal blooms worldwide. Persistent in freshwater supplies, microcystins are not degraded by boiling. To date, no hepatocellular toxicity assay has been established to monitor for comparative toxicity of microcystins due to the expression of OATP transporters responsible for microcystin uptake in established cell lines. It was hypothesized that aggregate culture of HEPG2 liver cells would increase relevant OATP expression as compared with two-dimensional culture due to increased cell-cell interactions and, thus, confer microcystin uptake and acute dose dependent toxicity in aggregate cultured cells as compared with controls. The specific aims were 1) to evaluate expression of OATP1B1 and OATP1B3 in aggregates relative to control culture, 2) to compare uptake of microcystins in aggregates relative to control, and 3) to compare microcystin toxicity to aggregates relative to control. Preliminary results have shown significantly increased mRNA expression of OATPs in aggregate culture relative to 2D culture ($p<0.05$, students t-test) at day 3 through day 7 of culture. Increased protein expression in aggregates relative to control is expected. Additionally, aggregate cultured HEPG2 cells are anticipated to demonstrate increased uptake of microcystins as compared with controls and, as such, increased sensitivity to toxicity. Despite identification of over 80 structural congeners, risk assessment and drinking water guidelines (WHO, EPA) are based on one sole congener, MC-LR. Animal deaths have been linked with other congeners. Diverse species effects suggest that mouse bioassay, the sole toxicity assay, may not be sufficient for predicting in vivo toxicity. Upon validation, this approach can be applied to compare toxicity of the congeners and to evaluate diverse species effects in vitro by modifying the approach for additional species cell lines.

Roitz, J. S., A. R. Flegal, et al. (2002). "The Biogeochemical Cycling of Manganese in San Francisco Bay: Temporal and Spatial Variations in Surface Water Concentrations." Estuarine, Coastal and Shelf Science 54(2): 227-239.

Pronounced variations in the distribution of dissolved manganese within the San Francisco Bay in 1995/96 reflect spatial and temporal variations in its biogeochemical and hydraulic regimes. In the northern reach of the system (North

Bay) dissolved Mn concentrations ranged from 12-210 nM at the freshwater interface, from 35-756 nM at intermediate salinities, and from 86-435 nM at the oceanic interface. At intermediate salinities in the southern reach (South Bay), the range in dissolved Mn concentrations (22-242 nM) was comparable to that of the northern reach. Dissolved Mn concentrations in the extreme South Bay, however, were one to two orders of magnitude higher (2800 nM) during the winter and even greater (5400 nM) during the summer. These high concentrations appear to be due to the relatively intense episodic diagenetic remobilization of Mn from benthic sediments. This proposed diagenetic remobilization of dissolved Mn followed a period of low dissolved Mn concentrations that occurred immediately after the spring bloom, which was attributed to the sorption of Mn onto phytoplankton, bloom-derived flocculent organic detritus, and associated bacteria. Copyright 2002 Elsevier Science Ltd

Rollwagen Bollens, G. C., S. M. Bollens, et al. (2006). "Vertical distribution of micro- and nanoplankton in the San Francisco Estuary in relation to hydrography and predators." Aquatic Microbial Ecology 44: 143-163.

Temperate estuaries are characterized by significant seasonal variability in the vertical salinity gradient, which, along with biological factors, may play a role in determining plankton vertical distribution. We examined the vertical distribution of microplankton (20 to 200 µm) and nanoplankton (~5 to 20 µm) in the San Francisco Estuary (SFE) over diel, seasonal and interannual time scales, and assessed the degree to which abiotic (hydrography) and biotic (predation) factors influenced these patterns. We sampled 2 hydrographically-distinct locations within the SFE: San Pablo Bay, a partially-mixed estuary, and South Bay, a lagoonal estuary. We conducted replicate Niskin bottle casts during the day and night at each location on 6 occasions between 1998 and 1999. We also conducted replicate day and night pump sampling for mesozooplankton (>153 µm) on 4 of these dates. The vertical distribution of micro- and nanoplankton was often homogeneous with depth, even under substantially different hydrographic conditions. ANOVA testing of weighted mean depths (WMD) of chlorophyll, major taxa of micro- and nanoplankton, and copepods (factors: location, year, season, time of day) revealed that only the microplankton taxa (specifically ciliates) showed significant differences in vertical distribution over the sampling period. The most significant differences in WMD were observed seasonally. Ciliates and copepods (Acartia spp.) showed significant diel differences in WMD on several occasions, but diel differences were rarely observed among other micro- and nanoplankton. The degree of salinity stratification was never correlated to WMD of any micro- or nanoplankton group, however vertical distributions of heterotrophic loricate and aloricate ciliates and dinoflagellates were often significantly correlated with distributions of chlorophyll and autotrophic nanoflagellates (presumed food), as well as with the vertical distributions of Acartia spp (presumed predators). We conclude that micro- and nanoplankton are often relatively homogeneously distributed with respect to depth in the SFE. However, when micro- and nanoplankton distributions were more heterogeneous, biotic factors had a greater influence on vertical distribution than abiotic factors (stratification) in the SFE.

Rollwagen Bollens, G. C. and D. L. Penry (2003). "Feeding dynamics of Acartia spp. copepods in a large, temperate estuary (San Francisco Bay, CA)." Marine Ecology Progress Series 257: 139-158.

We measured diet composition, prey preferences and feeding rates of Acartia spp., an abundant copepod group in San Francisco Bay. Monthly incubations with Acartia feeding upon the natural planktonic assemblage were conducted during spring 2000 at 2 locations: South Bay (SB, lagoonal estuary) and San Pablo Bay (SPB, partially mixed estuary). Prey assemblages in SB and SPB were always dominated by nanoplankton, however Acartia never consumed cells <10 µm in either location. Overall abundance >15 µm was always higher in SB, comprised primarily of autotrophic cells (diatoms and pigment-containing flagellates). The assemblage in SPB was typically dominated by heterotrophic prey (ciliates and small non-pigmented flagellates). Acartia consumed a diverse diet but were highly selective for motile prey, especially ciliates and nanoflagellates. Acartia selectivity for individual prey taxa was strongest during periods of high food abundance, consistent with optimal foraging theory. In SB at least 50% of Acartia diet consisted of autotrophic biomass (diatoms, flagellates and the autotrophic ciliate Mesodinium). Ingestion rates were low and accounted for only 6.3% of body carbon per day, except during the March bloom, when Acartia ingested diatom biomass at 217 ngC copepod-1 h-1, or 188% of body carbon per day. In SPB Acartia diets were dominated by heterotrophic prey >10 µm, with ciliates and non-pigmented flagellates always >60% of total biomass consumed. Ingestion rates were lower than in SB (typically equivalent to 2.2% of body carbon per day), but in the April bloom Acartia increased consumption of heterotrophic flagellates to 121 ngC copepod-1 h-1, or 101% of body carbon per day. These results indicate that protozoans provide an essential nutritional supplement for San Francisco Bay copepods, especially in SPB, and that bloom periods may be important for copepod production and, in turn, higher trophic levels.

Rook, B., J. Montgomery, C. Laskodi, C. Watry, and J. Merz (2010). Evaluating a spawning habitat enhancement project: Improving benthic macroinvertebrate production in gravel augmentation areas to benefit juvenile salmonid rearing habitat quality. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Coarse sediment recruitment and other related ecosystem processes have been interrupted on regulated California Central Valley rivers resulting in a general deficit of substrates appropriate for spawning salmonids. Within these areas, gravel augmentation has generally improved conditions for salmonid spawning, egg incubation and embryonic development. Benthic macroinvertebrate production is also enhanced and colonization of new gravels occurs relatively rapidly; however, these conditions don’t necessarily confer optimal benefits to potential prey items available to rearing juvenile salmonids, which also utilize these areas. In general, benthic macroinvertebrate communities respond to complex associations and interactions at the microhabitat scale, including water depth and velocity and substrate size. As a result, we hypothesized that by varying these parameters for target benthic macroinvertebrate species within ranges suitable for spawning salmonids, we would increase the amount of available prey appropriate for rearing juveniles, further improving these habitats. We utilized existing juvenile steelhead and Chinook salmon diet information from the lower American River to identify the top 4 most prevalent prey species, and the most appropriate prey size classes and life stages for fish at various sizes. We then used benthic macroinvertebrate samples collected across various habitat conditions (e.g., substrate size/type, depth, velocity) from previous investigations conducted in the lower American and Mokelumne rivers to develop suitability criteria to inform experimental gravel placement in the lower American River. We tested the effects of substrate size on the production of selected benthic macroinvertebrates by creating patches of larger substrate within newly placed gravel. We sampled areas with suitable velocities and depths for the selected prey species within those patches. These results were compared to data collected from control samples in the general augmentation area. Our results demonstrate increased target species biomass (per unit area) associated with the treatment patches compared to the control areas. This model will be developed as an adaptive management tool to establish design standards for planning future spawning gravel augmentation on the lower American River with potential for use throughout the Central Valley.

Roos, M. (1989). "Possible climate change and its impact on water supply in California." Oceans '89: 247-249.

Forecasts of historically large climate changes are being made by global climate modelers with warming of 3 to 8 degrees Fahrenheit (1.5 to 4.5 degree Celsius) by the middle of the next century. These changes, if they occur, would have profound impact on California's water resources. A substantial shift in runoff patterns would be expected, with loss of a large fraction of spring snowmelt. This shift will make it difficult or impossible to fill major multipurpose reservoirs once the flood control season is past, with losses in current water project water yields and hydroelectric power. The predicted rise in sea level would cause problems in the Sacramento-San Joaquin Delta, the hub of major water transfer in the state. There would be increased risk of levee failures in the Delta and a potential increase in salinity intrusion from the ocean which could affect water supplies of the central and southern portions of the state.

Rose, K. A., W. Kimmerer, K. Edwards, and W.A. Bennett (2010). Using an individual-based model to evaluate the factors affecting population dynamics of delta smelt. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Delta smelt has become increasingly controversial due to its long-term decline and the more recent pelagic organism decline (POD). To address some of the questions related to the causes for the decline, we developed an individual-based population dynamics model. The model tracks thousands of individuals on the same spatial grid as used by Department of Water Resource’s DSM2 hydrodynamics model. For computational reasons, we use a super-individual approach, whereby each model individual represents a number of identical population individuals. Daily water temperature, salinity, turbidity, and the densities of six zooplankton prey types are represented on the spatial grid. The model follows the reproduction, growth, mortality, and movement of individuals over their entire life cycle. Reproduction is evaluated daily and egg cohorts are tracked until hatching. New model individuals are introduced as individual yolk-sac larvae. Growth of later stages is based on bioenergetics and zooplankton densities. Mortality includes a constant rate plus mortality due to starvation, turbidity, and entrainment. Movement of individuals is by particle tracking for the larval stages and behavioral algorithms for juveniles and adults. We simulated the population decline using 1995 to 2005 conditions, and explored the relative influence of historical changes in food, entrainment, and female size on delta smelt population dynamics. Simulations indicate that all of these factors have an effect on delta smelt, with the potential for interactive effects causing unexpectedly large population responses. Increased understanding of how environmental conditions and pumping-related entrainment affect delta smelt population dynamics will inform the ecosystem restoration objective of restoring and protecting the habitats of native species. The modeling can be used to filter the many possible management actions that could be taken, helping to identify effective and efficient options from an ecological perspective.

Rosenfield, J. A. and R. D. Baxter (2007). "Population Dynamics and Distribution Patterns of Longfin Smelt in the San Francisco Estuary." Transactions of the American Fisheries Society 136(6): 1577-1592.

The San Francisco Estuary supports several endemic species of fish and the southernmost populations of other species. Many of these native species and populations are imperiled or have experienced recent population declines that indicate a general decline in the estuary's capacity to support pelagic fish species. We studied the distribution and abundance of one of the estuary's native species, longfin smelt Spirinchus thaleichthys, using data from three long-term aquatic sampling programs. Each of the sampling programs we studied revealed a substantial reduction in the abundance of longfin smelt. These trends support the idea that the estuary's capacity to support pelagic fish species has been significantly reduced over the past three decades. Longfin smelt in the estuary displayed consistent patterns in relative abundance and distribution during their life cycle. We also found significant, but weak, spatial autocorrelation among sampling stations. These patterns in distribution reveal differential habitat use and migratory behavior. Managers can use these insights into longfin smelt distribution patterns to improve interpretation of sampling program results.

Rossiter, M. (2010). Diversions from the Delta, Water Years 2008 and 2009. IEP Newsletter. 23: 2.

Rosso, P. H., S. L. Ustin, et al. (2005). "Mapping marshland vegetation of San Francisco Bay, California, using hyperspectral data." International Journal of Remote Sensing 26(23): 5169-5191.

Sustainable management of wetland ecosystems requires monitoring of vegetation dynamics, which can be achieved through remote sensing. This paper assesses the use of hyperspectral imagery to study the structure of wetlands of San Francisco Bay, California, USA. Spectral mixture analysis (SMA) and multiple endmember spectral mixture analysis (MESMA) were applied on an AVIRIS (Airborne Visible and Infrared Imaging Spectrometer) image to investigate their appropriateness to characterize marshes, with emphasis on the Spartina species complex. The role of rms. error as a measure of model adequacy and different methods for image endmember extraction were also evaluated. Results indicate that both SMA

and MESMA are suitable for mapping the main components of the marsh, although MESMA seems more appropriate since it can incorporate more than one endmember per class, rms. error was shown not to be a measure of SMA model adequacy, but it can be used to help to assess model adequacy within groups of related models.

Rosso, P. H., S. L. Ustin, et al. (2006). "Use of lidar to study changes associated with Spartina invasion in San Francisco Bay marshes." Remote Sensing of Environment 100(3): 295-306.
Extensive alteration of the tidal salt marshes of San Francisco Bay has created an urgent need to preserve the few remaining areas of relatively pristine tidal marshes. The dynamics of these marshes can be quantified and mapped using the high vertical and horizontal point density of airborne laser scanners (lidar) if their data quality is adequate. We evaluated lidar's ability to characterize wetland topography and vegetation structure, with emphasis on measuring short-term changes associated with the invasive Spartina. Measurable errors between flight lines and between laser returns were observed. By comparing lidar datasets with ground measurements we found that lidar did not reach the ground underneath vegetation. Nonetheless, change detection using digital surface models showed that Spartina markedly affected the accretion- erosion patterns of the shoreline and the water drainage patterns on the mudflat. With some exceptions, Spartina patches showed evident expansion patterns with rates of up to 2.5 m/year. Our study indicates that lidar has a great potential to discriminate Spartina species and marsh components, and to quantify sediment dynamics associated with the Spartina invasion, and changes in Spartina structure and biomass.

Roth, D. A., H. E. Taylor, et al. (2001). "Distribution of Inorganic Mercury in Sacramento River Water and Suspended Colloidal Sediment Material." Archives of Environmental Contamination and Toxicology 40(2): 161-172.
The concentration and distribution of inorganic Hg was measured using cold-vapor atomic fluorescence spectrometry in samples collected at selected sites on the Sacramento River from below Shasta Dam to Freeport, CA, at six separate times between 1996 and 1997. Dissolved (ultrafiltered, 0.005 mu m equivalent pore size) Hg concentrations remained relatively constant throughout the system, ranging from the detection limit (0.4 ng/L) to 2.4 ng/L. Total Hg (dissolved plus colloidal suspended sediment) concentrations ranged from the detection limit at the site below Shasta Dam in September 1996 to 81 ng/L at the Colusa site in January 1997, demonstrating that colloidal sediment plays an important role in the downriver Hg transport. Sequential extractions of colloid concentrates indicate that the greatest amount of Hg associated with sediment was found in the "residual (mineral) phase with a significant quantity also occurring in the "oxidizable phase. Only a minor amount of Hg was observed in the "reducible phase. Dissolved Hg loads remained constant or increased slightly in the downstream direction through the study area, whereas the total inorganic Hg load increased significantly downstream especially in the reach of the river between Bend Bridge and Colusa. Analysis of temporal variations showed that Hg loading was positively correlated to discharge.

Rozengurt, M. A. (1983). Our environmental approach to protecting estuaries from salt intrusion.

Rozengurt, M. A., M. Josselyn, et al. (1985). The impact of water diversions on the river-delta-estuary sea ecosystems of San Francisco Bay and the Sea of Azov.

Rubin, D. M. and D. S. McCulloch (1979). The movement and equilibrium of bedforms in central San Francisco Bay. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, AAAS: 97-113.

Rudek, J., and J.E. Cloern (1996). Planktonic respiration rates in San Francisco Bay. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science
AAAS: 289-304.

Rudnick, D. and V. Resh (2005). "Stable isotopes, mesocosms and gut content analysis demonstrate trophic differences in two invasive decapod crustacea." Freshwater

Biology 50(8): 1323-1336.
1. Improving our understanding of dietary differences among omnivorous, benthic crustacea can help to define the scope of their trophic influence in benthic food webs. In this study, we examined the trophic ecology of two non-native decapod crustaceans, the Chinese mitten crab (Eriocheir sinensis) (CMC) and the red swamp crayfish (Procambarus clarkii) (RSC), in the San Francisco Bay ecosystem to describe their food web impacts and explore whether these species are functionally equivalent in their impacts on aquatic benthic communities. 2. We used multiple methods to maximise resolution of the diet of these species, including N and C stable isotope analysis of field data, controlled feeding experiments to estimate isotopic fractionation, mesocosm experiments, and gut content analysis (GCA). 3. In experimental enclosures, both CMC and RSC caused significant declines in terrestrially derived plant detritus ($P < 0.01$) and algae ($P < 0.02$) relative to controls, and declines in densities of the caddisfly Gumaga nigricula by > 50% relative to controls. 4. Plant material dominated gut contents of both species, but several sediment-dwelling invertebrate taxa were also found. GCA and mesocosm results indicate that CMC feed predominantly on surface-dwelling invertebrates, suggesting that trophic impacts of this species could include a shift in invertebrate community composition towards sediment-dwelling taxa. 5. Stable isotope analysis supported a stronger relationship between CMC and both algae and algal-associated invertebrates than with allochthonous plant materials, while RSC was more closely aligned with terrestrially derived detritus. 6. The trophic ecology and life histories of these two invasive species translate into important differences in potential impacts on aquatic food webs. Our results suggest that the CMC differs from the RSC in exerting new pressures on autochthonous food sources and shallow-dwelling invertebrates. The crab's wide-ranging foraging techniques, use of intertidal habitat, and migration out of freshwater at sexual maturity increases the distribution of the impacts of this important invasive species.

Rudnick, D., T. Veldhuizen, et al. (2005). "A life history model for the San Francisco Estuary population of the Chinese mitten crab, Eriocheir sinensis (Decapoda : Grapsoidea)." Biological Invasions 7(2): 333-350.
First discovered in San Francisco Bay in 1992, the Chinese mitten crab,Eriocheir sinensis, has become established over hundreds of km(2) of the San Francisco Estuary. Ecological and economic impacts of this invasive species motivated our search for a greater understanding of the crabs life history as an important step in better management and control. Data for this life history model comes from the authors research and scientific literature. Juvenile crabs migrate from the Estuary into fresh water where they develop into adults. Environmental signals may stimulate gonad development that is followed by a downstream migration beginning at the end of summer. Mating occurs after the crabs reach saline water. Embryos are carried until hatching, and the larvae undergo five zoeal stages before settlement. Our model projects rates of development at various temperatures and growth increments, supports a minimum of 2 years in low salinity or freshwater habitat, and predicts that mo! st California mitten crabs are at least 3 years old before becoming sexually mature. Environmental factors strongly influence the timing and duration of the crabs life stages, and are discussed in the context of a gradient of development times for worldwide populations of this important invasive species.

Rudnick, D. A., V. Chan, et al. (2005). "Morphology and impacts of the burrows of the Chinese mitten crab, Eriocheir sinensis H. Milne Edwards (Decapoda, Grapsoidea), in South San Francisco Bay, California, U.S.A." Crustaceana 78(7): 787-807.
Juvenile Chinese mitten crabs,Eriocheir sinensis, create burrows, in both their native and introduced ranges, in soft-sediment banks of intertidal portions of streams. When mitten crab abundance is high, burrows can become very dense. In Europe, this behavior has been linked to erosion and bank collapse. To assess burrow morphology, patterns of use, and impacts to stream bank integrity, we conducted burrow casting and burrow transects in the intertidal portions of tributaries to South San Francisco Bay, California, between winter 2000 and winter 2002. Burrows were found between the high and low tide lines of streams, and contained at minimum a downward-sloping tunnel and saturated terminal chamber. Burrow morphology ranged from single tunnels with one terminal chamber containing one crab, to highly complex

burrows with multiple surface openings and tunnels containing multiple crabs. Casted burrows ranged in volume from 199 cm sub(3) to 1994 cm sub(3). Sediment adjacent to casted burrows was dominated by sand and silt; mitten crab burrows casted on a stream gravel bar were found to stop above a coarser gravelly mix underlying the sand/silt top layer. Densities and occupancy rates of burrows on sampled streams were variable among streams and seasons, with the highest occupancy rates generally occurring in spring and summer. Crabs removed an estimated 1 to 6% of sediment per 0.5 m sub(3) of stream bank through burrowing activities over the period of study. Localized areas of bank slumping were also noted, particularly in spring following rain events. The complex morphology of mitten crab burrows suggests that they are created, maintained, and reused over long periods of time, by multiple year classes of crabs. Sediment loss from burrowing activities may be substantial in this part of South San Francisco Bay, and is influenced by multiple factors including population abundance, connectivity of the burrow systems, and sediment composition.Original Abstract:

Rudnick, D. A., K. M. Halat, et al. (2000). Distribution, ecology and potential impacts of the Chinese mitten crab (Eriocheir sinensis) in San Francisco Bay, Water Resources Center Contribution #206, University of California.

Rudnick, D. A., K. Hieb, et al. (2003). "Patterns and processes of biological invasion: The chinese mitten crab in San Francisco Bay." Basic and Applied Ecology 4: 249-262.

The Chinese mitten crab, native to coastal rivers and estuaries of central Asia, has invaded several European countries over the past century, causing widespread concern because of its periodically extreme abundance and burrowing behavior that causes bank erosion. San Francisco Bay and its tributaries contain the first and, currently, only known established population of the Chinese mitten crab in North America. Discovered in South San Francisco Bay in 1992, the mitten crab has spread rapidly to cover several thousand km(2) surrounding the Bay. Between 1995 and 2001, we monitored distribution, population dynamics, and life history attributes of the Chinese mitten crab in San Francisco Bay and its tributaries. Burrow densities increased from a mean of 6 burrows/m(2) in 1995 to >30 burrows/m(2) in 1999 in tidal portions of South Bay tributaries. Mitten crabs are associated with: tidally influenced portions of Bay tributaries as young juveniles; with freshwater streams (less than or equal to250 km from their confluence with the Bay) as older, migrating juveniles; and with the open waters of the Bay as reproductive adults after migrating from fresh water to reproduce between late fall and early spring. Population size peaked in 1998, with 750,000 crabs counted in fall migration in a North Bay tributary and 2.5 crabs/tow collected from North Bay breeding grounds; abundance subsequently declined greatly (2500 crabs in the same river system, 0.8 crabs/tow). Average size of adult crabs diverged between the North Bay population, which increased in size between 1996 and 2001, and the South Bay population, which decreased. The rapid establishment and spread of this species, its tolerance for a wide range of biotic and abiotic conditions, and its cyclical population dynamics pose challenges for control.

Ruhl, C. A., D.H. Schoellhamer, R.P. Stumpf, and C.L. Lindsay. (2001). "Combined use of remote sensing and continuous monitoring to analyze the variability of suspended-sediment concentrations in San Francisco Bay, California." Estuarine, Coastal and Shelf Science 53(5): 801-812.

Analysis of suspended-sediment concentration data in San Francisco Bay is complicated by spatial and temporal variability. In situ optical backscatterance sensors provide continuous suspended-sediment concentration data, but inaccessibility, vandalism, and cost limit the number of potential monitoring stations. Satellite imagery reveals the spatial distribution of surficial-suspended sediment concentrations in the Bay; however, temporal resolution is poor. Analysis of the in situ sensor data in conjunction with the satellite reflectance data shows the effects of physical processes on both the spatial and temporal distribution of suspended sediment in San Francisco Bay. Plumes can be created by large freshwater flows. Zones of high suspended-sediment concentrations in shallow subembayments are

associated with wind-wave resuspension and the spring-neap cycle. Filaments of clear and turbid water are caused by different transport processes in deep channels, as opposed to adjacent shallow water.

Ruhl, C. A. and D. H. Schoellhamer (2004). "Spatial and temporal variability of suspended-sediment concentrations in a shallow estuarine environment." San Francisco Estuary and Watershed Science 2(2).
Shallow subembayments respond differently than deep channels to physical forces acting in estuaries. The U.S. Geological Survey measured suspended-sediment concentrations at five locations in Honker Bay, a shallow subembayment of San Francisco Bay, and the adjacent channel to investigate the spatial and temporal differences between deep and shallow estuarine environments. During the first freshwater pulse of the wet season, the channel tended to transport suspended sediments through the system, whereas the shallow area acted as off-channel storage where deposition would likely occur. Following the freshwater pulse, suspended-sediment concentrations were greater in Honker Bay than in the adjacent deep channel, due to the larger supply of erodible sediment on the bed. However, the tidal variability of suspended-sediment concentrations in both Honker Bay and in the adjacent channel was greater after the freshwater pulse than before. During wind events, suspended-sediment concentrations in the channel were not affected; however, wind played a crucial role in the resuspension of sediments in the shallows. Despite wind-wave sediment resuspension in Honker Bay, tidally averaged suspended-sediment flux was controlled by the flood-dominated currents.

Ruhl, C. A. and M. R. Simpson (2005). Computation of discharge using the index-velocity method in tidally affected areas. Sacramento, CA, U.S. Geological Survey.

Ryan, A., L. Parsons, and M. Patten (2010). Post-restoration plant community assembly patterns on the Giacomini Wetland Restoration Project. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Numerous projects in San Francisco Bay and central California seek to restore tidal marshes, the largest being the San Francisco and Napa salt pond projects. The 600-acre Giacomini Wetland Restoration Project, completed 2 years ago, offers an opportunity to examine the way in which tidal marsh plant communities form (or “assemble”) after restoration. Though located on Tomales Bay, the processes which shape community assemblage on Giacomini Wetlands are broadly applicable, and the outcomes offer lessons for other restoration projects. Generally more diverse than those currently found in San Francisco Bay, the salt marshes of Tomales Bay may reflect the historic diversity of San Francisco Bay marshes. We looked at several factors, including distance from channel and distance from a larger waterbody, elevation, salinity, and whether or not the soil surface was scraped during restoration, to evaluate what factors drove plant community assemblage. Many of these factors such as scraping, number of channels, and in some instances elevation, were manipulated during the restoration process. Initial data suggest that the main driver of plant community assembly was elevation, but that scraping the soil surface and distance from channel also had significant effects on plant community assemblage. In addition, the site appears to be undergoing succession: Atriplex triangularis, which dominated many areas the first year was much less common the second year. By comparing this site to a reference marsh we are able to evaluate its trajectory towards a “desired” future condition. While species number approaches that of the reference site, species evenness is much lower than the reference site and overall species diversity in year two remains significantly lower than the reference marsh.

Ryan, H. F. and M. A. Noble (2007). "Sea level fluctuations in central California at subtidal to decadal and longer time scales with implications for San Francisco Bay, California." Estuarine, Coastal and Shelf Science 73(3-4): 538-550.
Sea level elevations from near the mouth of San Francisco Bay are used to describe the low-frequency variability of forcing of the coastal ocean on the Bay at a variety of temporal scales. About 90% of subtidal fluctuations in sea level in San Francisco Bay are driven by the sea level variations in the coastal ocean that

propagate into the Bay at the estuary mouth. We use the 100-year sea level record available at San Francisco to document a 1.9mm/yr mean sea level rise, and to determine fluctuations related to El Nino-Southern Oscillation (ENSO) and other climatic events. At time scales greater than 1 year, ENSO dominates the sea level signal and can result in fluctuations in sea level of 10-15cm. Alongshore wind stress data from central California are also analyzed to determine the impact of changes in coastal elevation at the mouth of San Francisco Bay within the synoptic wind band of 2-30 days. At least 40% of the subtidal fluctuations in sea level of the Bay are tied to the large-scale regional wind field affecting sea level variations in the coastal ocean, with little local, direct wind forcing of the Bay itself. The majority of the subtidal sea level fluctuations within the Bay that are not related to the coastal ocean sea level signal are forced by an east-west sea level gradient resulting from tidally induced variations in sea level at specific beat frequencies that are enhanced in the northern reach of the Bay. River discharge into the Bay through the Sacramento and San Joaquin River Delta also contributes to the east-west gradient, but to a lesser degree.

Safran, R. J., C.R. Isola, M.A. Colwell, and O.E. Williams (1997). "Benthic invertebrates at foraging locations of nine waterbird species in managed wetlands of the northern San Joaquin Valley, California." Wetlands 17(3): 407-415.
The ecologies of waterbirds are closely tied to the distribution and abundance of food resources. For many species of waterfowl and shorebirds, benthic invertebrates (especially Chironomidae) are an important dietary component that influences habitat selection. Consequently, we sampled benthic invertebrates and measured water depth at foraging locations of nine waterbird species and paired random sites in the Grasslands of the northern San Joaquin Valley, California, USA from January to April 1994 and 1995. Our resulting habitat-selection models indicate significant differences in benthic invertebrate densities or biomasses at foraging and random locations for three of nine species and significant differences in water depths between foraging and random locations for four of nine species. Additionally, we observed significant interspecific differences in water depths at foraging locations—shorebirds used shallow habitats (<10 cm), whereas most waterfowl species foraged in deep water (>20 cm). Waterfowl foraged over a wider range of water depths than shorebirds, indicating greater behavioral flexibility in habitat use. Our results indicate that selection of foraging habitat by smaller bodied waterbirds, including dowitchers, dunlin, western sandpiper, and least sandpiper is strongly influenced by water depth, which mediates the availability of benthic invertebrates. Additionally, foraging site selection of more mobile taxa that are able to forage in a wide range of water depths, including northern shoveler and american green-winged teal, is influenced by invertebrate biomass. The broad range of water depths used by waterfowl and the relatively restricted depths used by shorebirds indicate that water depth can be manipulated to benefit a multitude of waterbird species.

Saiki, M. K. (1984). "Environmental conditions and fish faunas in low elevation rivers on the irrigated San Joaquin Valley floor." California Fish and Game 70: 145-157.

Saiki, M. K., and C.J. Schmitt (1985). "Population biology of bluegills, Lepomis macrochirus, in lotic habitats on the irrigated San Joaquin Valley floor (California, USA)." California Fish and Game 71(4): 225-244.
Rapid expansion of irrigated agriculture in the western Usa has prompted concerns for aquatic resources. Although the impacts of irrigation activities on quality and quantity of river water are well documented (e.g., high turbidity from soil erosion, eutrophication from nutrient runoff, pesticide contamination, reduced discharge), their effects on fish populations are still poorly understood. We studied the food, growth, and live weight (a measure of body condition) of bluegills, Lepomis macrochirus, in relation to environmental factors in reaches of the San Joaquin and Merced rivers that have been affected to varying degrees by irradiation return flows. Fry of bluegills ate mostly cladocerans and copepods; fingerlings and larger fish ate immature aquatic insects, terrestrial insects, amphipods, and mollusks. Bluegill stomachs were fuller and contained a higher diversity of forage taxa in habitats with low turbidity and conductivity, weak buffering capacity, and low nurtrient level; bluegills also ate a more diverse diet

where the potential forage supply (benthic macroinvertebrates) was most diverse. Bluegills attained mean total lengths of about 42 mm at age I, 86 mm at age Ii, 116 mm at age Iii, 153 mm at age Iv, and 166 mm at age Mean relative weight ranged from 96-11 Growth rate and relative weight were not significantly correlated with environmental or dietary variables. On the basis of our study, we concluded that environmental degradation from irrigation activities affected the diet of bluegills primarily by modifying the food supply, but growth rate and body condition were not affected.

Saiki, M. K., and C.J. Schmitt (1986). "Organochlorine chemical residues in bluegills (Lepomis macrochirus) and common carp (Cyprinus carpio) from the irrigated San Joaquin Valley floor, California (USA)." Archives of Environmental Contamination and Toxicology 15(4): 357-366.
Samples of bluegills (Lepomis macrochirus) and common carp (Cyprinus carpio) collected from the San Joaquin River and two tributaries (Merced River and Salt Slough) in California were analyzed for 21 organochlorine chemical residues by gas chromatography to determine if pesticide contamination was confined to downstream sites exposed to irrigated agriculture, or if nonirrigated upstream sites were also contaminated. Residues ofp,p-DDE were detected in all samples of both species. Six other contaminants were also present in both species at one or more of the collection sites: chlordane (cis-chlordane +trans-nonachlor);p,p-DDD;o,p-DDT;p,p-DDT; DCPA (dimethyl tetrachloroterephthalate); and dieldrin. Concentrations of most of these residues were generally higher in carp than in bluegills; residues of other compounds were found only in carp: -BHC (-benzenehexachloride), Aroclor 1260, and toxaphene. Concentrations of most organochlorines in fish increased from upstream to downstream. Water quality variables that are influenced by irrigation return flows (e.g., conductivity, turbidity, and total alkalinity) also increased from upstream to downstream and were significantly correlated (P < 0.05)="" with="" organochlorine="" residue="" levels="" in="" the="" fish.="" in="" carp,="" concentrations="" of="" two="">DDT (p,p-DDD +p,p-DDE + +p,p-DDT; 1.43 to 2.21 mg/kg wet weight) and toxaphene (3.12 mg/kg wet weight)-approached the highest levels reported by the National Pesticide Monitoring Program for fish from other intensively farmed watersheds of the United States in 1980 to 1981, and surpassed criteria for whole-body residue concentrations recomended by the National Academy of Sciences and National Academy of Engineers for the protection of piscivorous wildlife.

Saiki, M. K., and T.W. May (1988). "Trace element residues in bluegills and common carp from the lower San Joaquin River, California (USA) and its tributaries." Science of the Total Environment 74: 199-218.
Whole-body samples of bluegills (Lepomis macrochirus) and common carp (Cyprinus carpio) from the San Joaquin River and two tributaries (Merced River and Salt Slough) were analyzed to determine if the concentrations of any of nine elements were elevated as a result of exposure of the fish to agricultural subsurface (tile) drainage water. Highest concentrations (micrograms/g dry weight) detected were as follows (first number in each pair applies to bluegills and the second to carp): arsenic (As), 0.97 and 1.5; boron (B), 14 and 20; cadmium (Cd), 0.14 and 0.27; chromium (Cr), 2.7 and 2.2; mercury (Hg), 3.3 and 2.9; molybdenum (Mo), 2.8 and 3.6; nickel (Ni), 0.87 and 2.2; lead (Pb), 0.26 and 2.3; and selenium (Se), 3.2 and 5.5. The lowest concentrations were below the levels of detection, except for Hg (0.15 in bluegills and 0.12 in carp) and Se (0.43 and 0.56). As judged by comparisons with data from the National Contaminant Biomonitoring Program and other published surveys, the concentrations of B, Hg, Mo, and Se were moderately elevated in fish from several sites in the San Joaquin Valley. However, only the Se concentrations were positively correlated with water quality variables (e.g., total alkalinity, conductivity, and turbidity) known to be influenced by irrigation return flows. Historical data from one site (Salt Slough), where trace elements in whole fish have been measured since 1969, indicated that Se concentrations increased more than twofold between 1973 and 1977, but thereafter remained near 3.0 micrograms g-1 (dry weight basis), presumably due to the continuing practice of disposing seleniferous tile drainage water into the most convenient stream channel.

Saiki, M. K., and D.U. Palawski (1990). "Selenium and other elements in juvenile

striped bass from the San Joaquin Valley and San Francisco Estuary, California (USA)." Archives of Environmental Contamination and Toxicology 19(5): 717-730.
Concentrations of selenium and other trace elements were determined in 55 whole body samples of juvenile anadromous striped bass (Morone saxatilis) from the San Joaquin Valley and San Francisco Estuary, California. The fish (<1 yr old—the predominant life stage in the San Joaquin Valley) were collected in September–December 1986 from 19 sites in the Valley and 3 sites in the Estuary, and analyzed for the following elements: aluminum (Al), arsenic (As), boron (B), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), magnesium (Mg), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), strontium (Sr), vanadium (V), and zinc (Zn). When compared to concentrations in whole freshwater fish measured by surveys from other waters, a few samples contained higher levels, of As, Cd, Cu, Pb, and Se. The median concentrations of Al, As, Cu, Fe, Mg, Se, and Sr also differed significantly (P<0.05) among sites. However, only Se concentrations were highest (up to 7.9 g/g dry weight) in samples from Valley sites exposed to agricultural subsurface (tile) drainwater; concentrations were lower in samples collected elsewhere. Water quality variables—especially those strongly influenced by tile drainwater (conductivity, total dissolved solids, total alkalinity, and total hardness)—were also significantly correlated (P<0.05) with Se concentrations in fish. Selenium concentrations in striped bass from the Estuary were only one-fourth to one-half the concentrations measured in the most contaminated fish from the San Joaquin River.

Saiki, M. K., M.R. Jennings, and T.W. May (1992). "Selenium and other elements in freshwater fishes from the irrigated San Joaquin Valley, California." Science of the Total Environment 126(1-2): 109-137.
Arsenic (As), chromium (Cr), mercury (Hg), and selenium (Se) were measured in composite whole-body samples of five fishes – bluegill (Lepomis macrochirus), common carp (Cyprinus carpio), mosquitofish (Gambusia affinis), largemouth bass (Micropterus salmoides), and Sacramento blackfish (Orthodon microlepidotus) – from the San Joaquin River system to determine if concentrations were elevated from exposure to agricultural subsurface (tile) drainage. Except for Cr, the concentrations of these elements in fishes from one or more sites were elevated; however, only Se approached concentrations that may adversely affect survival, growth, or reproduction in warm water fishes. Moreover, only Se among the four measured elements exhibited a geographic (spatial) pattern that coincided with known inflows of tile drainage to the San Joaquin River and its tributaries. Historical data from the Grassland Water District (Grasslands; a region exposed to concentrated tile drainage) suggested that concentrations of Se in fishes were at maximum during or shortly after 1984 and have been slightly lower since then. The recent decline of Se concentrations in fishes from the Grasslands could be temporary if additional acreages of irrigated lands in this portion of the San Joaquin Valley must be tile-drained to protect agricultural crops from rising groundwater tables.

Saiki, M. K., and M.R. Jennings (1992). "Toxicity of agricultural subsurface drainwater from the San Joaquin Valley, California, to juvenile chinook salmon and striped bass." Transactions of the American Fisheries Society 121(1): 78-93.
Juvenile chinook salmon Oncorhynchus tshawytscha (40–50 mm total length, TL) and striped bass Morone saxatilis (30–40 mm TL) were exposed to serial dilutions (100, 50, 25, and 12.5%) of agricultural subsurface drainwater (WWD), reconstituted drainwater (RWWD), and reconstituted seawater (IO). Agricultural subsurface drainwater contained naturally elevated concentrations of major ions (such as sodium and sulfate) and trace elements (especially boron and selenium), RWWD contained concentrations of major ions that mimicked those in WWD but trace elements were not elevated, and IO contained concentrations of total dissolved salt that were similar to those in WWD and RWWD but chloride replaced sulfate as the dominant anion. After 28 d of static exposure, over 75% of the chinook salmon in 100% WWD had died, whereas none had died in other dilutions and water types. Growth of chinook salmon in WWD and RWWD, but not in IO, exhibited dilution responses. All striped bass died in 100% WWD within 23 d, whereas 19 of 20 striped bass had died in 100% RWWD after 28 d. In contrast, none died in 100% IO. Growth of striped bass was impaired only in WWD. Fish in WWD accumulated as much as 200 µg/g (dry-weight basis) of boron, whereas fish in control water accumulated less than 3.1 µg/g. Although potentially

toxic concentrations of selenium occurred in WWD (geometric means, 158–218 µg/L), chinook salmon and striped bass exposed to this water type accumulated 5.7 µg Se/g or less. These findings indicate that WWD was toxic to chinook salmon and striped bass. Judging from available data, the toxicity of WWD was due primarily to high concentrations of major ions present in atypical ratios, to high concentrations of sulfate, or to both. High concentrations of boron and selenium also may have contributed to the toxicity of WWD, but their effects were not clearly delineated.

Saiki, M. K., M.R. Jennings, and W.G. Brumbaugh (1993). "Boron, molybdenum, and selenium in aquatic food chains from the lower San Joaquin River and its tributaries, California." Archives of Environmental Contamination and Toxicology 24(3): 307-319.

Boron (B), molybdenum (Mo), and selenium (Se) were measured in water, sediment, particulate organic detritus, and in various biota—filamentous algae, net plankton, macroinvertebrates, and fishes—to determine if concentrations were elevated from exposure to agricultural subsurface (tile) drainage during the spring and fall 1987, in the San Joaquin River, California. Concentrations of B and Se, but not Mo, were higher in most samples from reaches receiving tile drainage than in samples from reaches receiving no tile drainage. Maximum concentrations of Se in water (0.025 g/mL), sediment (3.0 g/g), invertebrates (14 g/g), and fishes (17 g/g) measured during this study exceeded concentrations that are detrimental to sensitive warmwater fishes. Toxic threshold concentrations of B and Mo in fishes and their foods have not been identified. Boron and Mo were not biomagnified in the aquatic food chain, because concentrations of these two elements were usually higher in filamentous algae and detritus than in invertebrates and fishes. Concentrations of Se were lower in filamentous algae than in invertebrates and fishes; however, concentrations of Se in or on detritus were similar to or higher than in invertebrates and fishes. These observations suggest that high concentrations of Se accumulated in invertebrates and fishes through food-chain transfer from Se-enriched detritus rather than from filamentous algae.

Saiki, M. K., and F. Mejia (2009). "Fish-Use of the Alviso Island Ponds and Adjacent Waters in South San Francisco Bay Following the Breaching of Earthen Levees." California Fish and Game 95 (1): 1-15.

Saiki, M. K., D. T. Castleberry, et al. (1995). "Copper, cadmium, and zinc concentrations in aquatic food chains from the upper Sacramento River (California) and selected tributaries." Archives of Environmental Contamination and Toxicology 29, no. 4: 484-491.

Metals enter the Upper Sacramento River above Redding, California, primarily through Spring Creek, a tributary that receives acid-mine drainage from a US EPA Superfund site known locally as Iron Mountain Mine. Waterweed (Elodea canadensis) and aquatic insects (midge larvae, Chironomidae; and mayfly nymphs, Ephemeroptera) from the Sacramento River downstream from Spring Creek contained much higher concentrations of copper (Cu), cadmium (Cd), and zinc (Zn) than did similar taxa from nearby reference tributaries not exposed to acid-mine drainage. Aquatic insects from the Sacramento River contained especially high maximum concentrations of Cu (200 mg/kg dry weight in midge larvae), Cd (23 mg/kg dry weight in mayfly nymphs), and Zn (1,700 mg/kg dry weight in mayfly nymphs). Although not always statistically significant, whole-body concentrations of Cu, Cd, and Zn in fishes (threespine stickleback, Gasterosteus aculeatus; Sacramento sucker, Catostomus occidentalis; Sacramento squawfish, Ptychocheilus grandis; and chinook salmon, Oncorhynchus tshawytasch) from the Sacramento River were generally higher than in fishes from the reference tributaries.

Saiki, M. K., B. A. Martin, et al. (2001). "Copper, Cadmium, and Zinc Concentrations in Juvenile Chinook Salmon and Selected Fish-Forage Organisms (Aquatic Insects) in the Upper Sacramento River, California." Water, Air, & Soil Pollution 132(1-2): 127-139.

This study assessed the downstream extent and severity of copper (Cu), cadmium (Cd), and zinc (Zn) contamination from acid mine drainage on juvenile chinook salmon (Oncorhynchus tshawytscha) and aquatic insects over a roughly 270-km reach of the Sacramento River below Keswick Reservoir. During April-May 1998, salmon

were collected from four sites in the river and from a fish hatchery that receives water from Battle Creek. Salmon from river sites were examined for gut contents to document their consumption of various invertebrate taxa, whereas salmon from river sites and the hatchery were used for metal determinations. Midge (Chironomidae) and caddisfly (Trichoptera) larvae and mayfly (Ephemeroptera) nymphs were collected for metal determinations during April-June from river sites and from Battle and Butte creeks. The fish hatchery and Battle and Butte creeks served as reference sites because they had no history of receiving mine drainage. Salmon consumed mostly midge larvae and pupae (44.0%, damp-dry biomass), caddisfly larvae (18.9%), Cladocera (5.8%), and mayfly nymphs (5.7%). These results demonstrated that insects selected for metal determinations were important as fish forage. Dry-weight concentrations of Cu, Cd, and Zn were generally far higher in salmon and insects from the river than from reference sites. Within the river, high metal concentrations persisted as far downstream as South Meridian (the lowermost sampling site). Maximum concentrations of Cd (30.7 mu g g super(-1)) and Zn (1230 mu g g super(-1)), but not Cu (87.4 mu g g super(-1)), in insects exceeded amounts that other investigators reported as toxic when fed for prolonged periods to juvenile salmonids.

Saini, D. E. (2010). Larval delta smelt behavior in response to physical stimuli. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Sakanari, J. A., and M. Moser (1986). "Lesion induction by the plerocercoid Lacistorhynchus tenuis (Cestoda) and wound healing in the striped bass, Morone saxatilis." Journal of Fish Biology 28(3): 289-296.
San Francisco Bay-Delta striped bass, Morone saxatilis (Walbaum), form open lesions in response to a plerocercoid infection of Lacistorhynchus tenuis (Van Beneden, 1858) (Cestoda: Trypanorhyncha). Laboratory infection experiments showed that striped bass can be infected with the plerocercoids by ingesting infected copepods. Histological sections indicated that a cellular host response was mounted early in the infection period, and that despite the leucocytic infiltration the parasites continued to develop. However, at 3 months post-infection some of the plerocercoids began to degenerate, and lesions formed at this time and 14 months post-infection. Open lesions in adult striped bass collected from the field took 2 months to heal and were detectable for at least 22 months. Regeneration of the muscle tissue did not occur although the wound completely healed externally.

Salt, G. W. (1989). "Comparison of the diets and reproductive performances of two sympatric rotifers, Asplanchna girodi and Asplanchna priodonta." Freshwater Biology 22(3): 417-430.
(1)Diet composition and the production of embryos were measured in Asplanchna girodi and Asplanchna priodonta collected through 3 years in the San Joaquin-Sacramento delta of California. The two species are sympatric in low to moderate densities for 5 months of the year. (2) Despite marked differences in the structure of the trophi, both species consumed the same array of prey species. Percentage composition of the diet varied both intra- and interspecifically. The food niches of the two species appear to differ little from one another. (3) Individuals of Asplanchna girodi had a larger mean number of prey in the gut per individual than did those of A.priodonta, due to their larger size. Per unit volume, each species prey gathering performance was the same. Asplanchna priodonta produced more embryos per calculated unit volume of prey ingested than did A.girodi. (4) During spring, when both species were present in the plankton, A.priodonta did not capture Size Class 2 and 5 animals (volumes 0.09–1.0 μm3×106 and 3.0–3.5 μm3X106 respectively) nor large Synchaeta. Both these prey classes were in the diet during the summer and autumn months. Several hypotheses are examined as possible explanations for this phenomenon.

San Francisco Estuary, I. (1997). "Annual Report of the Regional Monitoring Program for Trace Substances. San Francisco Estuary Institute, Richmond, CA."

Sanderson, E. W., M. Zhang, et al. (1998). "Geostatistical scaling of canopy water content in a California salt marsh." Landscape Ecology 13(2): 79-92.

Remote sensing data are typically collected at a scale which is larger in both grain and extent than traditional ecological measurements. To compare with remotely sensed data on a one-to-one basis, field measurements frequently must be rescaled to match the grain of image data. Once a one-to-one correspondence is established, it may be possible to extrapolate site based relationships over a wider extent. This paper presents a methodology for rescaling the grain of ecological field data to match the grain of remotely sensed data and gives an example of the method in verification of remote sensing estimates of canopy water content in a tidal salt marsh. We measured canopy water content at 169 points on a semi-regular grid in the Petaluma Marsh, CA. A variogram describing the spatial correlation structure of the canopy water content was calculated and modeled. Ordinary kriging estimates of the canopy water content were calculated over blocks corresponding to image pixels acquired by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS). A water content index was determined from the reflectance data by calculating the area of a water absorption feature at 970 nm. A regression developed between the blocks and the pixels at the site was extrapolated over the image to obtain an estimate of canopy water content for the entire marsh. The patterns of canopy water content at the site and landscape levels suggest that different processes are important for determining patterns of canopy water content at different spatial extents. The errors involved in the rescaling procedures and the remote sensing interpretation are discussed.

Sandstrom, P., G. Singer, A. Amman, C. Michel, S. Lindley, B. Macfarlane, and P. Klimley (2010). Sacramento River steelhead trout: Comparing natural and hatchery smolts. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
There has been little research on the migratory movements of wild steelhead trout in the Sacramento River. It has been hypothesized that wild smolts will have a higher survival rate and behave differently than hatchery smolts. In order to examine this question steelhead trout surgically implanted with Vemco V7 acoutstic tags. 150 Coleman National Fish Hatchery smolts were tagged, and released, with 50 fish released at three locations (Jelly's Ferry RKM 517, Irvine Finch RKM 414, and Butte City RKM 363) during two different times of year, December 2008 and January 2009 for a total of 300 tagged individuals. 60 fish were captured in a rotary screw trap and implanted tagged from Mill Creek (RKM 462), a tributary to the mainstem Sacramento River. The purpose of this study was to track the migratory movements and survival of both wild and hatchery smolts throughout the Sacramento River Watershed. Route selection within the Delta and the success rate of fish navigating a particular route is also examined. The majority of steelhead, hatchery December (n=30), hatchery January (n=43), and wild (n=21) respectively, utilize the mainstem Sacramento River (63%, 48%, 47%) when moving through the Delta with considerable number of individuals using Georgiana Slough (20%, 25%, 28%), and a smaller proportion of fish using Steamboat (7%, 12%, 5%), Sutter (10%, 5%, 19%), and Miner Sloughs (0%, 9%, 0%). Fish that reached the Golden Gate Bridge migratory time averaged 20 (13-36 days), 23 (10-57 days), and 12 (10-15 days) days for hatchery December, hatchery January, and wild smolts.

Santos, M. J., E. L. Hestir, S. Khanna, J.K. Conrad, K. Weinersmith, A. Sih, and S.L. Ustin (2010). Aquatic plant communities in the Sacramento-San Joaquin River Delta: Ecological and monitoring challenges. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The Sacramento-San Joaquin Delta is a dynamic and complex ecosystem. It extends over 2500km2 of intricate waterways, where gradients of water depth, temperature, salinity, velocity, sediment, and plant and animal communities intersect and interact. Its geographical location makes it highly susceptible to biological invasions, and it is in the center of international shipping and the agricultural hub of the state. It is the major water source for the agricultural industry and most of the state's population. Because of this setting, the Delta faces significant challenges to understand its ecological interactions and processes at the landscape scale and how to effectively monitor trends and patterns. The goals of this poster are to illustrate strategies to monitor aquatic vegetation and management of the aquatic plant communities of the Delta, to develop an integrated

understanding of how these ecological processes interact with the abiotic environment, and to encourage managers and researchers to work collaboratively to understand and monitor such complex ecosystems. Here we present a short overview of four case studies that illustrate some of the challenges for adaptive ecosystem management: (I) Submerged plant community dynamics, (II) Emergent plant community dynamics, (III) Feedbacks between submerged plants and turbidity, and (IV) Feedbacks between submerged plants and fish species.

Santos, M. J., and S.L. Ustin (2010). Competition and niche limitations determine the pathway of aquatic plant succession in the Delta? 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Plant communities in aquatic ecosystems are established through successional processes, initially through sediment deposits in the river bed that allow plant colonization and establishment. Species in confined aquatic environments are exposed to two main pressures that can lead to compositional shifts: niche limitations and competitive structuring. To test whether either or both of these mechanisms are responsible for the current aquatic plant assemblages in the Sacramento-San Joaquin River Delta, we recorded species composition in over 1000 locations annually from 2004 to 2008, of which 328 were revisited every year. We found that the Delta is composed of variable communities, with a significant year effect. Rapid turnover in species composition and life form dominance occurred, from an emergent and wetland dominance in 2004-2005, towards a submerged dominance in 2006 and somewhat in 2007-2008, where only water was recorded at 50% of the revisited sites. Our results suggest that there is a synergistic effect of species interactions and niche limitations in structuring the aquatic community. The results suggest a stronger effect of species interactions that operates each year, while niche limitations occur in three out of the five years we surveyed the area. Our results also show two cycles of competitive community structuring, one from 2004 to 2006, and a new one in 2007 and 2008. The latter coincides with a decrease in Egeria densa biomass and cover as a result of herbicide applications, likely precipitating new species interactions or freeing other species from competition. Along with Egeria densa, Eichhornia crassipes, Hydrocotyle ranunculoides and Schoenoplectus californicus were considered strongly interacting species, the first two are Invasive Alien Species and the last two are natives. We propose that these are the species most likely dictating the pathways of succession in the Delta.

Santos, M. J., E.L. Hestir, S. Khanna, E. Duncan, and S.L. Ustin (2010). Imaging spectroscopy elucidates functional dissimilarity between native and non-native plant species in the aquatic environment. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Invasive Alien Species (IAS) can change or retain ecosystem functionality. Using field data and imaging spectroscopy we demonstrate that IAS and native submersed aquatic plants are functionally dissimilar at the metabolic, physiological and morphological levels. Spectral separability between water, native and non-native submersed plant species is due primarily to differences in the visible and near–infrared reflectance; differences that are attributable to leaf morphology and canopy structure. IAS have wider leaf blades, larger leaf area, their canopy is denser and evenly vertically distributed throughout the water column compared to the native species. This makes them more effective in capturing light in the Sacramento-San Joaquin River Delta’s turbid waters. We found that IAS have higher rates of photosynthesis in high light conditions as measured by Photochemical Reflectance Index [PRI]. This results in a significantly higher biomass production of the dominant IAS (Egeria densa) in monoculture than when it grows in mixed patches with other species. This suggests that competitive enhancement of IAS results from physiological traits for alternative metabolic pathways such as a facultative C4-mechanism and its carbon allocation patterns. Imaging spectroscopy opens a new avenue for invasibility studies; it elucidates differences in plant functionality that may have major ecosystem level implications.

Scanlan, L. A. A., E. Lachenauer, X. Lin, P. Luong, C. Tran, and C. Vulpe (2010). Flame-retardants and Daphnia magna. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Chemical flame-retardants have been used extensively in California since the 1970s. They are impregnated into consumer products such as furniture foam, upholstery, and electronics casings. However, since the chemicals are not covalently bonded to the materials in which they are added, they leach into the environment and end up in organisms such as humans, pets and marine animals. Very little data exists about the toxicity of flame-retardants in environmentally relevant organisms such as Daphnia magna. In this work, we address this question by determining the acute and chronic toxicity of flame-retardants in Daphnia. We are also pursuing gene expression studies to provide insight into mode of toxicity. Flame-retardants being tested include penta, octa- and deca- polybrominated diphenyl ethers (PBDEs) and penta-PDEs replacement formulation FireMaster550 (FM550). We are also testing FM550 components tetra-bromo phthalate (TBPH), triphenyl phosphate (TPP), and Firemaster BZ-54, which consists of TBPH and tetra-bromo benzoate (TBB).

Schaffter, R. G. (1997). "Age and growth of white catfish in California's Sacramento-San Joaquin Delta." California Fish and Game 83: 57-67.

Schaffter, R. G. (1997). "Growth of white catfish in California's Sacramento-San Joaquin Delta." California Fish and Game 83(2): 57-69.
California's Sacramento-San Joaquin Delta is inhabited by one of the slowest growing populations of white catfish, Ameiurus catus, yet reported. White catfish in the south and central delta grow more slowly than fish in the north and west delta. At age 8, white catfish in the south and central delta reach only 253 mm fork length; fish from the north and west delta are 284 mm long at the same age. After age 4, males grow faster than females in the south and central delta, but not in other areas. Lack of an adequate forage base for larger fish and high population densities may be responsible for slow growth. While angling regulations have been changed to increase harvest and, potentially, reduce density, meaningful increases in catch would probably require changes in allowable fishing gear that may adversely impact other species

Schaffter, R. G., and D.W. Kohlhurst (1997). "Mortality rates of white catfish in California's Sacramento-San Joaquin Delta." California Fish and Game 83(2): 45-56.
White catfish, Ameiurus catus, were tagged at 10 locations in the Sacramento-San Joaquin Delta in fall and early winter from 1978 to 1980. Estimated mean total annual mortality rates of fish greater than or equal to 240 mm fork length ranged from 0.31 in Beaver and Disappointment sloughs to 0.67 in the San Joaquin River at Mossdale. Estimated average annual exploitation rates of white catfish greater than or equal to 240 mm fork length varied from 0.14-0.18 in the northern delta to 0.25 in the San Joaquin River. Exploitation rate increased with fish size. In comparison with an earlier tagging study, mean total mortality decreased from 0.46-0.57 in 1953-1954 to 0.36-0.44 in 1978-1980, largely because of a decrease in fishing mortality.

Schaffter, R. G., and D.W. Kohlhurst (1997). "White sturgeon spawning migrations and location of spawning habitat in the Sacramento River, California." California Fish and Game 83(1): 1-20.
Sixty sturgeon (59 white, Acipenser transmontanus, and one green, A. medirostris) were tagged with radio transmitters in the lower Sacramento River in late winter 1990 and 1991 and their movements during spawning migrations were followed. In spring 1991 and 1992, artificial substrate samplers were deployed in various habitats in areas of the Sacramento River used by spawning sturgeon. Upstream movement of tagged sturgeon could be quite rapid, up to 25 km/d, and was often stimulated by small increases in river flow. Downstream movement of females, assumed to be post-spawning migrations, were also rapid, as fast as 91 km/d. Sturgeon eggs were taken at artificial substrate sites where depths ranged from 1.8 to 4.6 m and flow velocities exceeded 1.0 m/s. Most spawning occurred from Knights Landing to several kilometers upstream of Colusa.

Schaffter, R. G., and D.W. Kohlhurst (1999). "Status of white sturgeon in the Sacramento-San Joaquin Estuary." California Fish and Game 85(1): 37-41.

Schemel, L. E., and S. W. Hagar (1996). Dissolved inorganic nitrogen, phosphorus, and silicon in South San Francisco Bay. II. A case study of effects of local climate, and weather. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, American Association for the Advancement of Science AAAS: 217-236.

Schemel, L. E., S. W. Hagar, and D. Childers. (1996). The supply and carbon content of suspended sediment from the Sacramento River to San Francisco Bay. San Francisco Bay: The ecosystem. J. T. Hollibaugh. San Francisco, CA, Pacific Division of the American Association for the Advancement of Science: 237-260.

Schemel, L. E., M.H. Cox, S.W. Hager and T. R. Sommer (2002). "Hydrology and chemistry of floodwaters in the Yolo Bypass, Sacramento River System, California, during 2000." U.S. Geological Survey Water Resources Investigations Report 02-4202: 1-71.

Discharges to and floodwaters in the Yolo Bypass were sampled during winter and spring, 2000. The primary purpose of the study was to link changes in water quality in the Yolo Bypass to inflows from the Sacramento River (over Fremont Weir) and from four local streams that discharge to the west side of the floodplain. Specific conductance, chloride, sulfate, dissolved inorganic nutrients, dissolved organic carbon, particulate carbon and nitrogen, suspended particulate matter (mass), and selected dissolved metals were measured in most of the samples. When the Sacramento River was spilling over Fremont Weir, the water chemistry in the Yolo Bypass was very similar to that in the river except along the western margin of the floodplain where influences of local stream inflow were evident. When flow over Fremont Weir stopped, floodwaters drained from the Yolo Bypass, and the local streams were the major discharges as the floodwaters receded eventually to the perennial channel along the eastern margin of the floodplain. After the initial draining of the floodplain, chemical concentrations at sites along the perennial channel showed strong influences of inflows from Cache Creek and Ridge Cut, which are sources of nutrients and contaminants that are potentially hazardous to wildlife. Runoff from spring storms increased flow in the perennial channel and flushed accumulated nutrients and organic matter to the tidal river. Releases of freshwater to the perennial channel might be beneficial in maintaining habitat quality for aquatic species during the dry seasons.

Schemel, L. E., T.R. Sommer, A.B. Muller-Solger, and W.C. Harrell (2004). "Hydrologic variability, water chemistry, and phytoplankton biomass in a large floodplain of the Sacramento River, CA, USA." Hydrobiologia 513(1-3): 129-139.

The Yolo Bypass, a large, managed floodplain that discharges to the headwaters of the San Francisco Estuary, was studied before, during, and after a single, month-long inundation by the Sacramento River in winter and spring 2000. The primary objective was to identify hydrologic conditions and other factors that enhance production of phytoplankton biomass in the floodplain waters. Recent reductions in phytoplankton have limited secondary production in the river and estuary, and increased phytoplankton biomass is a restoration objective for this system. Chlorophyll a was used as a measure of phytoplankton biomass in this study. Chlorophyll a concentrations were low (<4>g l-1) during inundation by the river when flow through the floodplain was high, but concentrations rapidly increased as river inflow decreased and the floodplain drained. Therefore, hydrologic conditions in the weeks following inundation by river inflow appeared most important for producing phytoplankton biomass in the floodplain. Discharges from local streams were important sources of water to the floodplain before and after inundation by the river, and they supplied dissolved inorganic nutrients while chlorophyll a was increasing. Discharge from the floodplain was enriched in chlorophyll a relative to downstream locations in the river and estuary during the initial draining and later when local stream inflows produced brief discharge pulses. Based on the observation that phytoplankton biomass peaks during drainage events, we suggest that phytoplankton production in the floodplain and biomass transport to downstream locations would be higher in years with multiple inundation and draining sequences.

Schemel, L. E. and S. W. Hager (1986). "Chemical variability in the Sacramento River and in northern San Francisco Bay." Estuaries 9: 270-283.

Specific conductance and concentrations of alkalinity, dissolved silica, nitrate, and ammonium were measured daily in the Sacramento River flow to northern San Francisco Bay during the rainfall seasons of 1983 and 1984 (high flow) and during late summer and early fall of 1984 (low flow). Flow and concentrations of chemical species varied in response to storm events during high flow, but flow was more variable than concentrations of chemical species. Runoff from agriculturally developed areas appeared to increase specific conductance and concentrations of alkalinity during high flow. During low flow, inputs of agricultural tailwaters caused variations in concentrations of alkalinity and dissolved silica. Dilution of municipal waste by river flow caused variability in concentrations of ammonium during both high flow and low flow. Distributions of alkalinity, dissolved silica, nitrate, and ammonium were measured in northern San Francisco Bay during late summer and fall of 1984. Changes in distributions of alkalinity in the estuary were caused by variations in alkalinity in the Sacramento River. Changes in distributions of dissolved silica, nitrate, and ammonium appeared to be primarily related to variations in supply by the river and removal by phytoplankton. Effects of removal by phytoplankton were large for ammonium and dissolved silica, but appeared relatively small for nitrate.

Schemel, L. E., S. W. Hager, et al. (1996). The supply and carbon content of suspended sediment from the Sacramento River to San Francisco Bay. San Francisco Bay: The Ecosystem. J. T. Hollibaugh. San Francisco, AAAS: 237-260.

Schemel, L. E., D. D. Harmon, et al. (1984). Response of northern San Francisco Bay to riverine inputs of dissolved organic carbon, silicon, nitrogen and phosphorus. The estuary as a filter. V. S. Kennedy. New York?, Academic Press: 221-240.
Estuarine processes can be effective in modifying (filtering) distributions of dissolved inorganic forms of carbon (DIC), silicon (DIS), nitrogen (DIN), and phosphorus (DIP) in northern San Francisco Bay. During winter, high inflow from the Sacramento-San Joaquin river system supplied these nutrients to the estuary at rates that exceeded potential rates of estuarine supply and removal processes. During spring and summer, when inflow rates were lower, the estuary was an effective "filter" of the river inflow "signal" because rates of estuarine processes were high relative to river and other supply rates. At lower inflow rates, the river apparently influenced estuarine hydrodynamic features that controlled rates of phytoplankton nutrient removal. Largest biological removal effects were localized in San Palo Bay during spring and Suisun Bay during summer, and they were generally more pronounced in shallow water areas of the bays. In San Pablo Bay, effects of biological removal appeared soon after river inflow decreased from high winter rates, but persisted for only a short time. During the following summer months, DIN and DIP distributions in San Pablo Bay indicated that estuarine sources contributed to higher concentrations of these nutrients.

Schile, L., M. Vasey, V.T. Parker, J. Callaway, E. Herbert, and N.M. Kelly (2010). Tidal wetland vegetation diversity gradients across and within sites in the San Francisco Bay Estuary. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The San Francisco Bay Estuary wetland landscape is a mosaic of natural and restored wetlands that fall along a large-scale salinity gradient. Within individual wetlands, there is also a strong inundation gradient from the wetland-bay margin to bordering uplands. This setting provides an ideal study location to examine how both salinity and inundation gradients affect plant species distribution. Predicted

climate change effects include accelerated sea-level rise and increased salinity, and these changes likely would shift species distributions across the Bay and further constrict the range of freshwater wetland species. We examined vegetation presence and abundance across six sites throughout the Bay to identify current distributions. We conducted vegetation surveys at ten randomly selected 3m diameter plots nested in twenty randomly selected 0.1 ha plots, for a total of 1200 plots. We supplemented these data with another set of random points stratified along channel edges. Channel inundation data were collected at each site for 1.5 years and, at a subset of survey points, elevation data were collected. Total species per plot, total species per 0.1 hectare plot, and total species per site were tabulated. Site-level richness was greater at sites along the Suisun Bay and western Delta, and decreased with increasing salinity. At many of the sites, plant diversity increased with proximity to the channel edge; the strength of this relationship decreased with decreasing salinity, while mid- and upper-marsh diversity increased along this same salinity gradient. Certain dominant species were consistently found at lower elevations (Schoenoplectus acutus) that were inundated frequently while others were inundated less frequently (Schoenoplectus americanus). This study provides the basis for increasing the understanding of current species distributions along salinity and inundation gradients that will allow us to predict how distributions might shift with climate change.

Schlekat, C. E., P. R. Dowdle, et al. (2000). "Bioavailability of Particle-Associated Se to the Bivalve Potamocorbula amurensis." Environmental Science and Technology 34(21): 4504-4510.

Elemental selenium, Se(0), is a prevalent chemical form in sediments, but little is known about its bioavailability. We evaluated the bioavailability of two forms of Se(0) by generating radioisotopic super(75)Se(0) through bacterial dissimilatory reduction of super(75)SeO super(2) sub(3) super(-) by pure bacterial cultures (SES) and by an anaerobic sediment microbial consortium (SED). A third form was generated by reducing super(75)SeO super(2) sub(3) super(-) with ascorbic acid (AA). Speciation determinations showed that AA and SES were >90% Se(0), but SED showed a mixture of Se(0), selenoanions, and a residual fraction. Pulsechase techniques were used to measure assimilation efficiencies (AE) of these particulate Se forms by the bivalve Potamocorbula amurensis. Mean AE values were 3 plus or minus 2% for AA, 7 plus or minus 1% for SES, and 28 plus or minus 15% for SED, showing that the bioavailability of reduced, particle-associated Se is dependent upon its origin. To determine if oxidative microbial processes increased Se transfer, SES super(75)Se(0) was incubated with an aerobic sediment microbial consortium. After 113 d of incubation, 36% of SES Se(0) was oxidized to SeO super(2) sub(3) super(-). Assimilation of total particulate Se was unaffected however (mean AE = 5.5%). The mean AE from the diatom Phaeodactylum tricornutum was 58 plus or minus 8%, verifying the importance of Se associated with biogenic particles. Speciation and AE results from SED suggest that selenoanion reduction in wetlands and estuaries produces biologically available reduced selenium.

Schlekat, C. E., B. G. Lee, et al. (2002). "Assimilation of selenium from phytoplankton by three benthic invertebrates: Effect of phytoplankton species." Marine Ecology Progress Series 237: 79-85.

Phytoplankton are an important source of selenium (Se) for aquatic invertebrates, which accumulate Se primarily through dietary ingestion. The extent to which Se bioavailability varies among different phytoplankton species could help explain different bioaccumulation patterns observed for invertebrates in nature. We measured the efficiency with which 3 benthic invertebrates assimilated super(75)Se from 5 phytoplankton species using standard pulse-chase techniques. The invertebrates included the amphipod Leptocheirus plumulosus and the bivalves Macoma balthica and Potamocorbula amurensis. The phytoplankton species included Cryptomonas (Cryptophyceae), Gymnodinium sanguinem (Dinophyceae), Phaeodactylum tricornutum (Bacillariophyceae), Synechococcus (Cyanophyceae) and Thalassiosira pseudonana (Bacillariophyceae). The range of Se assimilation efficiency (AE) by L. plumulosus (32.1 plus or minus 1.8 to 69.5 plus or minus 7.1%) was the lowest of the 3 organisms. No relationship was observed between the proportion of Se in algal cell cytoplasm and Se AE by L. plumulosus, which is consistent with findings for assimilation of other trace elements by this organism. Se AE by M. balthica (range:

58.0 plus or minus 3.2 to 92.3 plus or minus 6.0%) varied according to the proportion of cytoplasmic Se in algal cells (p < 0.0001, r super(2) = 0.868). P. amurensis assimilated between 78.3 plus or minus 2.0 and 88.9 plus or minus 3.6% of Se from algal cells, and the relationship between cytoplasmic Se and Se AE was described by the following equation: Se AE = 69.2 + 0.22 x (% cytoplasmic Se) (p = 0.003, r super(2)= 0.405). This relationship suggests that P. amurensis assimilated non-cytoplasmic Se from phytoplankton, perhaps through utilization of the glandular digestive pathway. Consistently high Se assimilation from algae by P. amurensis may contribute to elevated Se concentrations observed for this organism.

Schlekat, C. E., D. G. Purkerson, et al. (2004). "Modeling selenium bioaccumulation through arthropod food webs in San Francisco Bay, California, USA." Environmental Toxicology and Chemistry 23(12): 3003-3010.

Trophic transfer is the main process by which upper trophic level wildlife are exposed to selenium. Transfers through lower levels of a predator's food web thus can be instrumental in determining the threat of selenium in an ecosystem. Little is known about Se transfer through pelagic, zooplankton-based food webs in San Francisco Bay ([SFB], CA, USA), which serve as an energy source for important predators such as striped bass. A dynamic multipathway bioaccumulation model was used to model Se transfer from phytoplankton to pelagic copepods to carnivorous mysids (Neomysis mercedis). Uptake rates of dissolved Se, depuration rates, and assimilation efficiencies (AE) for the model were determined for copepods and mysids in the laboratory. Small (73-250 mum) and large (250-500 mum) herbivorous zooplankton collected from SFB (Oithonal Limnoithona and Acartia sp.) assimilated Se with similar efficiencies (41-52%) from phytoplankton. Mysids assimilated 73% of Se from small herbivorous zooplankton; Se AE was significantly lower (61%) than larger herbivorous zooplankton. Selenium depuration rates were high for both zooplankton and mysids (12-25% d(-1)), especially compared to bivalves (2-3% d(-1)). The model predicted steady state Se concentrations in mysids similar to those observed in the field. The predicted concentration range (1.5-5.4 mug g(-1)) was lower than concentrations of 4.5 to 24 mug g(-1) observed in bivalves from the bay. Differences in efflux between mysids and bivalves were the best explanation for the differences in uptake. The results suggest that the risk of selenium toxicity to predators feeding on N. mercedis would be less than the risk to predators feeding on bivalves. Management of selenium contamination should include food webs analyses to focus on the most important exposure pathways identified for a given watershed.

Schlenk, D. (2010). A risk based approach to evaluate the potential impact of synthetic pyrethroid insecticides on aquatic organisms of the San Francisco Bay Delta. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Schlenk, D., R. Lavado, J. Loyo-Rosales, W. Jones, L. Maryoung, N. Riar, I. Werner, and D. Dedlak (2012). "Reconstitution Studies of Pesticides and Surfactants Exploring the Cause of Estrogenic Activity Observed in Surface Waters of the San Francisco Bay Delta." Environmental Science & Technology 46(16): 6.

To evaluate the potential role of endocrine disruption in the decline of pelagic fishes in the San Francisco Bay Delta of California, various surface water samples were collected, extracted, and found to elicit estrogenic activity in laboratory fish. Chemical analysis of the estrogenic samples indicated 2 pesticides (bifenthrin, diuron), 2 alkyphenols (AP), and mixtures of 2 types of alkyphenol polyethoxylates (APEOs). Evaluation of estrogenic activity was further characterized by in vitro bioassays using rainbow trout hepatocytes (Oncorhynchus mykiss) and in vivo studies with Japanese medaka (Oryzias latipes). In the in vitro bioassays, hepatocytes exposed to the pesticides alone or in combination with the AP/APEO mixtures at concentrations observed in surface waters failed to show estrogenic activity (induction of vitelloginin mRNA). In the in vivo bioassays, medaka exposed to individual pesticides or to AP/APEO alone did not have elevated VTG at ambient concentrations. However, when the pesticides were combined with AP/APEOs in the 7-day exposure a significant increase in VTG was observed. Exposure to a 5-fold higher concentration of the AP/APEO mixture alone also significantly induced VTG. In contrast to earlier studies with permethrin, biotransformation of bifenthrin to estrogenic metabolites was not observed in medaka liver microsomes and cytochrome

P450 was not induced with AP/APEO treatment. These results showed that mixtures of pesticides with significantly different modes of action and AP/APEOs at environmentally relevant concentrations may be associated with estrogenic activity measured in water extracts and feral fish that have been shown to be in population decline in the San Francisco Bay Delta.

Schneider, K. R. and B. Helmuth (2007). "Spatial variability in habitat temperature may drive patterns of selection between an invasive and native mussel species." Marine Ecology Progress Series 339: 157-167.

To understand the mechanisms of invasions it is necessary to explore how thermal environments affect the distribution of both native and invasive species. We examined patterns of species distribution at several scales to determine how thermal selection affects the distribution of native (Mytilus trossulus) and invading (M. galloprovincialis) mussels inhabiting marine rocky intertidal and subtidal habitats. Previous work on these species has focused on the role of water temperature in setting distribution patterns, neglecting the role of aerial exposure at low tide. We therefore examined patterns of abundance in shaded and sun-exposed intertidal habitats and in intertidal versus subtidal habitats at sites within the San Francisco Bay over 3 yr. At half (2/4) of the sites the abundance of the native mussel was significantly higher in shaded intertidal habitats compared to warmer, sun-exposed intertidal habitats, where the invasive mussels were more abundant. Additionally, when comparisons were made between paired subtidal and intertidal sites, native mussel abundance was higher in subtidal habitats. In general, however, there was an unexplained and steady decrease in M. trossulus abundance at all sites. Field transplant experiments showed that the native mussel had lower survivorship than the invading species in all habitats examined (subtidal, shaded, and sun-exposed intertidal). Overall survivorship was lowest for both species in the sun- exposed intertidal treatments. This study shows that physiological stress associated with aerial exposure is likely to contribute to the local and geographic distribution of these mussel species. Moreover, our results suggest that processes that operate over larger geographic scales may be experimentally detectable over much smaller scales.

Schoellhamer, D. H. (1994). "Suspended-solids concentrations in central San Francisco Bay during 1993 winter runoff." Eos Transactions of the American Geophysical Union 72: 122.

Schoellhamer, D. H. (1996). "Factors affecting suspended-solids concentrations in South San Francisco Bay, California." Journal of Geophysical Research 101(C5): 12087-12095.

Measurements of suspended solids concentration (SSC) were made at two depths at three sites in South San Francisco Bay (South Bay) to determine the factors that affect SSC. Twenty eight segments of reliable and continuous SSC time series data longer than 14 days were collected from late 1991 or 1992 through September 1993. Spectral analysis and singular spectrum analysis were used to relate these data segments to time series of several potential forcing factors, including diurnal and semidiurnal tides, the spring neap tidal cycle, wind shear, freshwater runoff, and longitudinal density differences. SSC is greatest during summer when a landward wind shear is applied to South Bay by the afternoon sea breeze. About one half the variance of SSC is caused by the spring neap cycle, and SSC lags the spring neap cycle by about 2 days. Relatively short duration of slack water limits the duration of deposition of suspended solids and consolidation of newly deposited bed sediment during the tidal cycle, so suspended solids accumulate in the water column as a spring tide is approached and slowly deposit as a neap tide is approached. Perturbations in SSC caused by wind and local runoff from winter storms during the study period were usually much smaller than SSC variations caused by the spring neap cycle. Variations of SSC at the study sites at tidal timescales are tidally forced, and nonlinear physical processes are significant. Advective transport dominates during spring tides when water with higher SSC due to wind wave resuspension is advected to the main channel from shallow water, but during neap tides, advective transport is less significant. The findings of this and other studies indicate that the tidally averaged transport of suspended solids responds to seasonal variations of wind shear in South Bay.

Schoellhamer, D. H. (1998). The weak influence of flocculation at low salinities on the distribution of suspended-solids concentration in the San Francisco Bay estuary, California, USA. Proceedings of the Fifth International Conference on Cohesive Sediment Transport, May 1998, Seoul, Korea.

Schoellhamer, D. H. (2001). Influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay. Coastal and estuarine fine sediment processes. W. H. McAnally, and A.J. Mehta. Amsterdam, Netherlands, Elsevier: 343-356.

Time series of salinity and suspended-solids concentration measured at four locations and vertical profiles of salinity and suspended-solids concentration measured during 48 water quality cruises from January 1993 to September 1997 are analyzed to describe the influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay, California. Estuarine turbidity maxima form when salinity is present but they are not associated with a singular salinity. Bottom topography enhances salinity stratification, gravitational circulation and estuarine turbidity maxima formation seaward of sills. The spring/neap tidal cycle affects locations of estuarine turbidity maxima. Salinity stratification in Carquinez Strait, which is seaward of a sill, is greatest during neap tides, which is the only time when tidally averaged suspended-solids concentration in Carquinez Strait was less than that observed landward at Mallard Island. Spring tides cause the greatest vertical mixing and suspended-solids concentration in Carquinez Strait. Therefore, surface estuarine turbidity maxima always were located in or near the Strait (seaward of Middle Ground) during spring tide cruises, regardless of salinity. During neap tides, surface estuarine turbidity maxima always were observed in the landward half of the study area (landward of Middle Ground) and between 0–2 practical salinity units.

Schoellhamer, D. H. (2002). "Comparison of basin-wide effect of dredging and natural estuarine processes on suspended-sediment concentration." Estuaries and Coasts 25(3): 488-495.

Suspended sediment concentration (SSC) data from San Pablo Bay, California, were analyzed to compare the basin-scale effect of dredging and disposal of dredged material (dredging operations) and natural estuarine processes. The analysis used twelve 3-wk to 5-wk periods of mid-depth and near-bottom SSC data collected at Point San Pablo every 15 min from 1993–1998. Point San Pablo is within a tidal excursion of a dredged-material disposal site. The SSC data were compared to dredging volume, Julian day, and hydrodynamic and meteorological variables that could affect SSC. Kendall’s τ, Spearman’s ρ , and weighted (by the fraction of valid data in each period) Spearman’s ρw correlation coefficients of the variables indicated which variables were significantly correlated with SSC. Wind-wave resuspension had the greatest effect on SSC. Median water-surface elevation was the primary factor affecting mid-depth SSC. Greater depths inhibit wind-wave resuspension of bottom sediment and indicate greater influence of less turbid water from down estuary. Seasonal variability in the supply of erodible sediment is the primary factor affecting near-bottom SSC. Natural physical processes in San Pablo Bay are more areally extensive, of equal or longer duration, and as frequent as dredging operations (when occurring), and they affect SSC at the tidal time scale. Natural processes control SSC at Point San Pablo even when dredging operations are occurring.

Schoellhamer, D. H. (2002). "Comparison of the Basin-scale Effect of Dredging Operations and Natural Estuarine Processes on Suspended Sediment Concentration." Estuaries 25(3): 488-495.

Suspended sediment concentration (SSC) data from San Pablo Bay, California, were analyzed to compare the basin-scale effect of dredging and disposal of dredged material (dredging operations) and natural estuarine processes. The analysis used twelve 3-wk to 5-wk periods of mid-depth and near-bottom SSC data collected at Point San Pablo every 15 min from 1993-1998. Point San Pablo is within a tidal excursion of a dredged-material disposal site. The SSC data were compared to dredging volume, Julian day, and hydrodynamic and meteorological variables that could affect SSC. Kendall's tau , Spearman's rho , and weighted (by the fraction of valid data in each

period) Spearman's rho sub(w) correlation coefficients of the variables indicated which variables were significantly correlated with SSC. Wind-wave resuspension had the greatest effect on SSC. Median water-surface elevation was the primary factor affecting mid-depth SSC. Greater depths inhibit wind-wave resuspension of bottom sediment and indicate greater influence of less turbid water from down estuary. Seasonal variability in the supply of erodible sediment is the primary factor affecting near-bottom SSC. Natural physical processes in San Pablo Bay are more areally extensive, of equal or longer duration, and as frequent as dredging operations (when occurring), and they affect SSC at the tidal time scale. Natural processes control SSC at Point San Pablo even when dredging operations are occurring.

Schoellhamer, D. H. (2002). "Variability of suspended-sediment concentration at tidal to annual time scales in San Francisco Bay, USA." Continental Shelf Research 22: 1857-1866.

Singular spectrum analysis for time series with missing data (SSAM) was used to reconstruct components of a 6-yr time series of suspended-sediment concentration (SSC) from San Francisco Bay. Data were collected every 15 min and the time series contained missing values that primarily were due to sensor fouling. SSAM was applied in a sequential manner to calculate reconstructed components with time scales of variability that ranged from tidal to annual. Physical processes that controlled SSC and their contribution to the total variance of SSC were (1) diurnal, semidiurnal, and other higher frequency tidal constituents (24%), (2) semimonthly tidal cycles (21%), (3) monthly tidal cycles (19%), (4) semiannual tidal cycles (12%), and (5) annual pulses of sediment caused by freshwater inflow, deposition, and subsequent wind-wave resuspension (13%). Of the total variance 89% was explained and subtidal variability (65%) was greater than tidal variability (24%). Processes at subtidal time scales accounted for more variance of SSC than processes at tidal time scales because sediment accumulated in the water column and the supply of easily erodible bed sediment increased during periods of increased subtidal energy. This large range of time scales that each contained significant variability of SSC and associated contaminants can confound design of sampling programs and interpretation of resulting data.

Schoellhamer, D. H. (2009). "Teaching Estuarine Hydrology with Online Data." Estuaries and Coasts 32(6): 1069-1078.

Abstract The transfigurative development of automated online data sources from estuaries, coastal oceans, and their watersheds provides a tremendous opportunity for use by educators. In this article, one approach tailored for San Francisco Bay and its watershed is presented. Hydrology can broadly be defined as the study of the properties and distribution of water. Multidisciplinary hydrologic characteristics that are exemplified by typical online data include spatial variability, temporal variability, forcing mechanisms, historical context, and extreme events. Data analysis and manuscript preparation allow students to develop and utilize scientific skills such as critical reading of the literature, evaluating data sources and quality, writing and data presentation, and conducting peer review. The goal of this approach is to use recent local real-world data and publication to motivate graduate students to study estuaries and coastal oceans.

Schoellhamer, D. H. (2010). Hydrology of San Francisco Bay and Watershed, Water Years 2008 and 2009. IEP Newsletter. 23: 2.

Schoellhamer, D. H. (2011). "Sudden Clearing of Estuarine Waters upon Crossing the Threshold from Transport to Supply Regulation of Sediment Transport as an Erodible Sediment Pool is Depleted: San Francisco Bay, 1999." Estuaries and Coasts 34(5): 885-899.

Schoellhamer, D. H., Wright, S.A., and Drexler, J.Z. (2012). "Conceptual Model of Sedimentation in the Sacramento-San Joaquin River Delta: ." San Francisco Estuary and Watershed Science 10(3): 9.

Sedimentation in the Sacramento–San Joaquin River Delta builds the Delta landscape, creates benthic and

pelagic habitat, and transports sediment-associated contaminants. Here we present a conceptual model of sedimentation that includes submodels for river supply from the watershed to the Delta, regional transport within the Delta and seaward exchange, and local sedimentation in open water and marsh habitats. The model demonstrates feedback loops that affect the Delta ecosystem. Submerged and emergent marsh vegetation act as ecosystem engineers that can create a positive feedback loop by decreasing suspended sediment, increasing water column light, which in turn enables more vegetation. Sea-level rise in open water is partially countered by a negative feedback loop that increases deposition if there is a net decrease in hydrodynamic energy. Manipulation of regional sediment transport is probably the most feasible method to control suspended sediment and thus turbidity. The conceptual model is used to identify information gaps that need to be filled to develop an accurate sediment transport model.

Schoellhamer, D. H. and J. R. Burau (1998). Summary of findings about circulation and the estuarine turbidity maximum in Suisun Bay, California.

Schoellhamer, D. H., T. E. Mumley, et al. (2007). "Suspended sediment and sediment-associated contaminants in San Francisco Bay." Environmental Research 105(1): 119-131.

Water-quality managers desire information on the temporal and spatial variability of contaminant concentrations and the magnitudes of watershed and bed-sediment loads in San Francisco Bay. To help provide this information, the Regional Monitoring Program for Trace Substances in the San Francisco Estuary (RMP) takes advantage of the association of many contaminants with sediment particles by continuously measuring suspended-sediment concentration (SSC), which is an accurate, less costly, and more easily measured surrogate for several trace metals and organic contaminants. Continuous time series of SSC are collected at several sites in the Bay. Although semidiurnal and diurnal tidal fluctuations are present, most of the variability of SSC occurs at fortnightly, monthly, and semiannual tidal time scales. A seasonal cycle of sediment inflow, wind-wave resuspension, and winnowing of fine sediment also is observed. SSC and, thus, sediment-associated contaminants tend to be greater in shallower water, at the landward ends of the Bay, and in several localized estuarine turbidity maxima. Although understanding of sediment transport has improved in the first 10 years of the RMP, determining a simple mass budget of sediment or associated contaminants is confounded by uncertainties regarding sediment flux at boundaries, change in bed-sediment storage, and appropriate modeling techniques. Nevertheless, management of sediment-associated contaminants has improved greatly. Better understanding of sediment and sediment-associated contaminants in the Bay is of great interest to evaluate the value of control actions taken and the need for additional controls.

Scholtz, N. (2010). Integrating conservation ecology and toxicology. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Scholz, N. L., E. Fleishman, et al. (2012). "A Perspective on Modern Pesticides, Pelagic Fish Declines, and Unknown Ecological Resilience in Highly Managed Ecosystems." BioScience 62(4): 428-434.

Schraga, T., J.E. Cloern, and R. Kudela (2010). How well do you know your light attenuation coefficient? A cautionary tale of two PAR sensors. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The depth of light penetration has large ramifications for aquatic ecosystems as it determines the amount of photosynthetically active radiation (PAR)

available to phytoplankton and benthic primary producers. In the San Francisco Bay-Delta (SFBD), the vertical attenuation coefficient for downwelling PAR, KPAR, is regularly used for numerous purposes, such as computation of primary production and as an index of habitat quality. Two types of PAR sensor, cosine and scalar, are commonly used in coastal ecosystems but were designed to measure different radiometric quantities. We caution scientists that it is relevant which sensor is used to calculate KPAR in SFBD. We collected 681 side by side depth profiles of PAR from cosine and scalar sensors during 20 months of regular monitoring cruises throughout SFBD. KPAR was calculated as the slope of the least-squares regression of the natural log of PAR against depth. On average, KPAR from the scalar sensor was 8.2% lower than the cosine sensor and as much as 40% lower in some cases. Undetected, scalar KPAR would have introduced an erroneous trend of reduced system turbidity in our 40 year dataset that historically used cosine KPAR. We calculated daily phytoplankton gross primary production (GPP) for both sensor’s KPAR using a biomass-depth-light model built for cosine KPAR. The GPP overestimate from using scalar KPAR was 10% on average and as high as 75% on multiple days. Hydrolight model runs explain the observed sensor differences, and further demonstrate that for this estuary, there is no one simple correction to convert one sensor KPAR to the other that will be spatially and temporally applicable. Consistency of methodology for measuring KPAR is especially significant when considering long term trends and modeling of the Bay-Delta system.

Schreier, B., M. Baerwald, B. May, and G. Schumer (2010). Detecting predation of larval delta smelt (Hypomesus transpacificus) by Mississippi silversides (Menidia audens) and other predators using genetic analysis of gut contents. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Schreier, B., M. Baerwald, B. May, T.R. Sommer, and G. Schumer (2010). Detecting predation of larval delta smelt by Mississippi silversides and other predators using genetic analysis of gut contents. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
“Top down” predation effects are an important part of the Pelagic Organism Decline (POD) conceptual model and thus are theorized to have substantial impacts on the threatened delta smelt (Hypomesus transpacificus). Particular interest has been placed on Mississippi silversides (Menidia audens) because their numbers have been increasing over recent years, and they readily consume delta smelt larvae in captivity. Thus, there is a need to evaluate whether wild silversides are impacting, or have the potential to impact, delta smelt recruitment. Given the difficulty of morphologically identifying larval fish remains in stomach contents, we developed a genetic assay to look for delta smelt DNA in the guts of putative predators of larval smelt. The assay was tested for cross-reactivity with a suite of delta fishes, and Mississippi silversides were utilized for captive feeding trials to characterize the assay and model the degradation of DNA in the predator guts. Additional sensitivity analyses demonstrated the assay’s ability to detect 0.1 picograms of target DNA in 100 nanograms of predator DNA. Upon development of the assay, beach seines were conducted in the Sacramento deep water ship channel to sample silversides and other predators (centrarchids and striped bass) for gut analysis. A total of 658 silversides, 13 striped bass, 11 yellow-fin gobies, and two centrarchids were collected for genetic gut analysis. Development and characterization of this genetic assay will provide a cost-efficient and powerful tool for researchers studying top-down effects on POD species in the delta, and it will have broad applications for detecting delta smelt presence. Results from the analysis of the guts of putative larval smelt predators will provide valuable insight into the impacts of predation on early life stages of delta smelt.

Schroeter, R., and P.B. Moyle (2010). Depth shifts: Consequences to the striped bass population in the San Francisco Estuary, California. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Erosion of sediments has resulted in the deepening of the San Francisco Estuary since the 19th century, with poorly understood consequences to fishes. I investigated changes in sampling depths at fixed otter trawl sampling stations in

Suisun Bay (CDFG Bay Study Survey) from 1980 to 2008 to determine if observed declines in juvenile striped bass abundance could be related to depth changes. Significant increases in sampling depth were observed in 9 of 11 Suisun Bay monitoring sites, consistent with the continued erosion of bay sediments. The increase in sampling depths resulted in greater representation of deep water sites (>7 m), which by the end of the study outnumbered shallow water sites (<7 m) by a 2:1 ratio. Juvenile bass declined significantly in all depths, but 70-94% of the catch occurred in shallow water samples. The temporal shift in site depth and the low catch in deep water samples have affected the comparability of annual abundance estimates for striped bass, as well as the accuracy of long term abundance trends. These findings point out that a change in the physical characteristics of the SFE can influence a species' apparent long term trend and should be considered when evaluating the results and effectiveness of monitoring programs.

Schroeter, R., and P.B. Moyle (2010). Distribution and implications of alien clams in Suisun Marsh, CA. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Clams can have a large effect on plankton in estuaries. This has been demonstrated in the San Francisco Estuary by the invasion of Corbula amurensis, which through its efficient filtering capabilities and high densities has contributed to the decline in phytoplankton in the upper estuary. This study investigates the distribution of C. amurensis and its freshwater counterpart Corbicula fluminea in Suisun Marsh with the goal of elucidating factors that may be constraining their abundance in this highly productive marsh. The effect of clam grazing on the phytoplankton biomass in Suisun Marsh is also investigated. This study utilizes data from a 2-year (2003-2005) CALFED funded investigation on the Suisun Marsh invertebrate community and a 30 year time trend (1980-2009) on the Suisun Marsh clam distribution using the UCD/IEP Suisun Marsh monitoring study.

Schuler, C. A., R. G. Anthony, et al. (1990). "SELENIUM IN WETLANDS AND WATERFOWL FOODS AT KESTERSON-RESERVOIR, CALIFORNIA, 1984." Archives of Environmental Contamination and Toxicology 19(6): 845-853.

Schumer, G., and B. Cavallo (2010). Developing real time quantitative PCR (Q-PCR) for rapid and reliable identification of Delta fish and invertebrates. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Q-PCR is a technique based on conventional PCR, which is used to amplify and simultaneously quantify a targeted DNA molecule. It enables both detection and quantification (as absolute number of copies or relative amount when normalized to DNA input) of one or more specific sequences in a mixed sample. A common method for detection of products in Q- PCR is based on the design of sequence-specific DNA probes consisting of oligonucleotides labeled with a fluorescent reporter, which permits detection only after hybridization of the probe with its complementary DNA target. PCR based identification of prey items and Q-PCR based detection of prey items is a proven technique (King et al. 2008, Rose et al. 2002) and is already in use by CFS/IEP/UC Davis staff to identify Delta Smelt, Longfin Smelt, and Wakasagi Smelt in the stomachs of Delta piscivores. High throughput technology based on Q-PCR methods are currently available for the development of a “gene chip” which will enable rapid, cost effective assessment of available and consumed biomass for all (dozens to hundreds) of Delta prey items (including zooplankton, macro invertebrates, fish and mollusks). The Fluidigm® BioMark™ Real Time PCR system allows for the simultaneous detection of up to 96 individual species for 96 samples in the same time it currently takes to detect 1 species. This platform for species identification will enable the processing of 9216 assays on 1 “gene chip.” Use of a “gene chip” will make it possible to provide a detailed assessment of available prey and diet composition among Delta fish species. Results are superior to classic visual identification of stomach contents because genetic methods allow even degraded or cryptic species in fish stomachs to be identified with a high degree of certainty.

Schwartz, R. S. and B. May (2004). "Characterization of microsatellite loci in Sacramento perch (Archoplites interruptus)." Molecular Ecology Notes 4(4): 694-697.

We characterized 23 polymorphic tetranucleotide microsatellite loci for Sacramento perch (Archoplites interruptus). This species is extirpated in its native range, the Sacramento-San Joaquin Delta (California, USA), and is therefore targeted for recovery. A concerted effort is currently underway to re-establish self-sustaining populations of Sacramento perch in its native range. These microsatellites will be used to analyse the population structure of the species and, in conjunction with life history and physiological data, develop a comprehensive recovery plan.

Seavy, N., T. Gardali, C. Hickey, M. Reiter, and R. DiGaudio (2010). Incorporating economic costs into wildlife habitat management: Examples from Central Valley riparian restoration and wetlands. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Problem Statement: There is now substantial evidence that incorporating economic considerations into conservation planning results in outcomes that are more ecologically effective and more cost efficient. However, there remain relatively few examples from the California where an explicit economic framework has been used to inform habitat management decisions. Approach and Results: We applied an economic framework to restoration and conservation in two ecological systems in the Central Valley. Riparian bird habitat restoration: Using models that quantify the bird response to restoration design elements with cost estimates for those same elements, we evaluated whether increased investments results in greater improvements in bird habitat. We found that the added cost of increasing the complexity of elements resulted in increased ecological benefits as measured by the response of the riparian bird community.Optimizing private lands programs for shorebirds and waterfowl: We used a linear programming approach to find a minimum cost solution to providing habitat in two landscapes (agriculture and semi-permanent wetlands) for shorebirds and waterfowl in order to meet minimum species’ population objectives and allow for constraints that limit the feasibility of some solutions. We found that meeting both shorebird and waterfowl objectives through incentive-based programs on semi-permanent wetlands and post-harvest flooded croplands requires 10s of millions of dollars each year in the Tulare Basin alone. In contrast, meeting 100% of shorebird population objectives only would be substantially less costly (about 1 million dollars) and provide habitat for 5% of the waterfowl objectives. Conclusions: Our results demonstrate that incorporating economic costs into restoration and conservation programs can provide information that can be used to improve conservation and restoration decision making in the Bay-Delta ecoregion.

Seesholtz, A., B. J. Cavallo, et al. (2004). Juvenile Fishes of the Lower Feather River: Distribution, Emigration Patterns, and Associations with Environmental Variables. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 141-166.

In the Feather River below Lake Oroville, California, the relative importance of water temperature and flow regimes on fish populations was assessed by comparing two distinct river segments, the low flow channel (LFC) and high flow channel (HFC). Rotary screw traps and beach seining surveys were used to assess distribution, abundance, and emigration patterns of fishes between 1997 and 2001. Both sampling methods revealed similar patterns in species composition. Chinook salmon Oncorhynchus tshawytscha dominated seining (46%) and rotary screw trap (99%) catch by number. More than 80% of Chinook salmon captured were less than 50 mm, demonstrating that most Feather River Chinook salmon emigrate before smolting. In multiple linear regression models, Chinook salmon spawn timing ($P < 0.001$) and water temperature ($P = 0.036$) were statistically significant predictors of weekly Chinook salmon catch in the LFC, while Secchi depth was statistically significant ($P = 0.007$) for the HFC catch. Most steelhead Oncorhynchus mykiss were captured in the LFC, particularly in 2001, which accounted for 82% of all steelhead collected. The total relative abundance of alien fishes was low, 7.2% and 0.1% from beach seining and rotary screw trap sampling, respectively. Alien fishes were more abundant in the HFC. Native fish species were found throughout the study area. Canonical correspondence analysis suggested that river kilometer, water temperature, and year were highly significant ($P = 0.001$), while season ($P = 0.01$) and flow ($P = 0.01$) were significant to observed fish assemblages within LFC. Water temperature, river

kilometer, year, and season were highly significant (P = 0.001) to observed fish assemblages within the HFC. Our results demonstrate that native fishes can be successful in a regulated river environment, despite an unnatural flow regime. These findings provide valuable information in assessing the impacts of dam operations and in implementing river restoration actions by flow and water temperature manipulation.

Service, R. F. (2007). "ENVIRONMENTAL RESTORATION: Delta Blues, California Style." Science 317(5837): 442-445.

Service, U. S. F. a. W. (1992). "Abundance and survival of juvenile chinook salmon in the Sacramento-San Joaquin Estuary."

Setzler-Hamilton, E. M., J. A. Whipple, et al. (1988). "Striped bass populations in Chesapeake and San Francisco Bays: Two environmentally impacted estuaries." Marine Pollution Bulletin 19(9): 466-477.

Striped bass (Morone saxatilis) populations have declined precipitously in both Chesapeake Bay and the San Francisco Bay Delta system. Parallel declines in both systems indicate possible common climatic patterns or trends affecting both populations. Climatic instability on both coasts with accompanying changes in average rainfall, outflow and temperature may be interacting with deteriorating water quality and pollution resulting in declining populations of striped bass in both areas.

Shahcheraghi, R. a. A. C. (2010). Delta Water Project Operations. IEP Newsletter. 23: 2.

Shellenbarger, G., S.A. Wright, and D.H. Schoellhamer (2010). Sediment flux in the southern reach of San Francisco Bay: implications for habitat restoration. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The South Bay Salt Pond Restoration Project is restoring about 6,000 hectares of former commercial salt-evaporation ponds to tidal marsh or managed wetlands in the southern reach of San Francisco Bay (SFB). As a result of groundwater overdrafts prior to the 1970s, much of the project area has subsided below sea-level and will require about 32 million cubic meters of sediment to raise the surface of the subsided areas to tidal marsh elevations. However, previous estimates of sediment flux between northern SFB and the southern reach using data from five bathymetry surveys conducted decades apart are insufficient to estimate the natural sediment supply from the bay. The specific purpose of this study is to quantify the continuous suspended-sediment flux (SSF) past Dumbarton Narrows. Data from two optical turbidity sensors and an acoustic Doppler current profiler mounted in the cross-section are collected every 15-minutes. Water discharge and velocity-weighted cross-sectionally averaged suspended-sediment concentrations (SSC) are measured during monthly site visits. Using the “index-velocity” method for discharge and a combination of turbidity and acoustic backscatter calibrated to SSC, a continuous (15-minute interval) record of SSF at the measurement cross-section is computed. Additionally, a high-accuracy pressure transducer and water-quality sonde are deployed on an adjacent intertidal mudflat to measure wave-height and turbidity, which provide evidence about the physical processes controlling SSF. Results suggest that, from November 2008 to October 2009, net sediment transport into southern SFB was from the north. Seasonality in SSF shows the largest southerly flux in the spring during periods of high SSC and not during the summer when strong diurnal winds from the north originally were thought to control the annual SSF. Understanding physical controls on sediment flux for this large wetland restoration project can explain how southern SFB and the project are linked to the rest of the estuary.

Shellenbarger, G. G. and D. H. Schoellhamer (2011). "Continuous Salinity and Temperature Data from San Francisco Estuary, 1982–2002: Trends and the Salinity–Freshwater Inflow Relationship." Journal of Coastal Research: 1191-1201.

Shelton, M. L. and R. M. Fridirici (1997). "Decadal changes of inflow to the

Sacramento San Joaquin delta, California." Physical Geography 18(3): 215-231.
The Sacramento-San Joaquin Delta is both an important environmental resource and a critical link in the water supply system for California. Concern for the adequacy of Delta water supplies increases with growing population and environmental maintenance needs and with the hydroclimatic uncertainty of global warming. Reconstructed or unimpaired discharges for Delta tributary areas are analyzed for trend and for changes in the seasonal regime of Delta inflows. Nonparametric tests indicate the absence of trend for annual inflows, but the low inflow months of September and October display increasing trends that are statistically significant. Additional changes in the Delta inflow regime are evident when inflow volumes are expressed relative to annual inflow. Decreasing trends in the spring fraction of annual total inflows and in the monthly fractions for April and May are statistically significant. March displays a significant increasing trend in the monthly fraction of inflow. The emerging decadal changes in monthly inflows have practical ramifications for water managers in the Delta.

Shilling, F., and G. Golet (2010). Effectiveness monitoring for the Sacramento River Riparian System. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The riparian systems of the Central Valley and Bay-Delta tributaries have been severely impacted by decades of land water management practices. One of CALFED’s major investments was in the restoration of riparian forest, channel processes, and more natural flows to benefit the riparian system. Combined with other sources of funding, thousands of acres have been acquired by various non-profit organizations and state and federal agencies. The majority of this land was horticulturally-restored. A key question has been, have these investments been effective and how can we tell when and where they have been? The Sacramento River Monitoring and Assessment Program investigated this question with several studies of vegetation characteristics at landscape and plot scales, modeling of the potential movement of the channel, and appropriate indicators for measuring success. The SRMAP Monitoring Plan is a key component of the overall program as it ties past changes with future monitoring and change detection programs. It includes measurement of biotic and abiotic attributes and processes. It is the basis for the indicator-based SRMAP Report Card, which provides an objective assessment of the riparian system condition. Effectiveness research is becoming an increasingly important policy tool as it makes a direct connection between financial investment and ecological returns. Measuring investment returns in ecological restoration depends, as it does in socio-economic systems, on comprehensive monitoring.

Shilling, F., M. Antos, and D. Waetjen (2010). Multi-scale, integrated reporting system for Bay-Delta regions. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
California and the Bay-Delta system in particular needs a reporting system that describes scientific understanding of ecological and socio-economic status and trends in ways that the public and decision-makers can understand. Reporting conditions and how these conditions change and are influenced encourages participation in knowledge and policy networks that have formed around big social and ecological issues in the state (e.g., water management through the Delta). In 2008, three state-funded regional programs began developing a science and stakeholder-input based reporting system that included environmental, social, and economic indicators of whole system status and trends. The North Bay program (led by Napa County) focused on the Napa River and its watershed as an appropriate model unit for the Bay-Delta; the Central Valley program (led by the Sacramento River Watershed Program) focused on the Feather River system, arguably the most important managed water system in the state; the Southern California program (led by the Los Angeles & San Gabriel Rivers Watershed Council) focused on the Los Angeles River and the Arroyo Seco in particular. All three programs selected goals and objectives for ecological, social, and economic conditions from extensive stakeholder input. Indicator sets were selected for each measurable objective and filtered through selection criteria to develop feasible, yet scientifically meaningful sets of system-indicators. The programs collected all available data and measured system-indicator conditions relative to reference standards for poor and good conditions to normalize indicator “scores” to a 0-100 scale. These normalizations

included non-linear transformations where appropriate (e.g., fish sensitivity to water temperature). Trends analyses were performed using the Mann-Kendall series of tests (including the Seasonal and Regional Kendall tests). The outcome was the development of a consistent and scalable approach for California for measuring and reporting whole system condition relative to stakeholder expectations for condition, using contemporary scientific literature and statistical tools.

Shukla, P. (2010). Determining run-type using otolith 87Sr/86Sr ratios among Feather River Chinook salmon spawners, 2002-2008. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Problem Statement: Central Valley Chinook salmon populations exhibit 4 distinct runs based primarily on the timing of upstream spawning migrations from the ocean. The fall-run is currently the largest population, followed by late-fall, spring and the endangered winter-run. The runs differ in many life history traits, the one most important for this research is the time fish spend in-river prior to spawning. However due to hatchery practices and climate change the distinction between runs has become less distinct. On the Feather River, spring-run Chinook migrate upstream in late spring and spend several months in-river, while fall-run spawn only a few days to a week prior to spawning, thus offspring from spring-run Chinook derive much of their nutrients from freshwater sources, while fall-run derive their nutrients from a marine source. This difference can be recorded in the chemical constituents of the otoliths and be used to determine the run designation of unmarked hatchery or wild fish. Approach: To help address these resource management challenges for Feather River fall and spring-run Chinook, we analyzed the microchemistry of otoliths collected during seven years of salmon carcass surveys with a subset of these fish with information regarding run-type from coded wire tags to serve as a validation. We measured the Sr isotope ratios (87Sr/86Sr) across the otolith with a laser, scanning from dorsal to ventral side encompassing the core (mothers contribution of Sr) the early juvenile periods (natal river contribution to Sr) and the migration period to the ocean. Our results show that the pattern in Sr isotope ratios (87Sr/86Sr) from core to juvenile period can be used to determine the run-type, with greater than 95% accuracy in classification to run-type based on coded wire tag records. However we do find a significant proportion of hatchery derived fish in the Feather River with an intermediate Sr isotope ratio (87Sr/86Sr) in the otoliths core, suggesting there is overlap in the time spent in-river prior to spawning . Conclusion/Implications for CALFED: This study supplies managers critical information regarding the designation of run-type to Chinook salmon on the Central Valley and provides for better management and monitoring of Chinook salmon.

Siegel, S., P. Bachand, D. Gillenwater, S. Chappell, B. A. Bergamaschi, B. Downing, M. Stephenson, W. Heim, C. Enright, and P.B. Moyle (2010). Landscape-scale considerations in restoring ecosystem functions in Suisun Marsh and Bay. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Significant depressions in dissolved oxygen (DO) concentrations and elevated levels of methylmercury (MeHg) have been observed at certain times of the year in several sloughs in northwestern Suisun Marsh that coincide with discharges from managed wetlands along these sloughs. Shifts in aquatic community structure in impacted sloughs to dominance by low-DO tolerant species, and in some cases even fish kills, have co-occurred with these events. The purpose of the project was to understand the contribution of managed wetland discharges to low DO and elevated MeHg events in Suisun Marsh and to develop best management practices for reducing such events. The study involved two years of data collection at two managed wetlands in northwest Suisun Marsh and their adjacent sloughs. Within the wetlands we collected data on water quality, water level, soil properties, topography, and vegetation. Within the sloughs we collected data on water quality, water level, flow, and aquatic biology. Baseline data were also collected in three managed wetlands in central Suisun Marsh for comparison. The results indicate that, following fall flood-up, the water within the managed wetlands routinely has low DO and elevated levels of dissolved organic carbon and MeHg. This water, when discharged to surrounding sloughs during fall drain events, causes an immediate drop in slough DO levels. Fall flood-up also causes net upstream flow in these sloughs, thereby reducing mixing with larger sloughs. Water quality within the wetlands and

sloughs generally improves by winter, but spring drain events from the wetlands still result in DO sags within the sloughs, though not as severe as in the fall. We recommend several wetland management changes that may help to reduce the impacts upon greater Suisun Marsh. These changes are focused on water, vegetation, and soil management within wetlands and improved communication and coordination between wetland managers and regulatory/resource agencies.

Siegfried, C. and M. Kopache (1980). "Feeding of Neomysis mercedis (Holmes)." Biological Bulletin 159: 193-205.
The diet of the opossum shrimp, N. mercedis , in the Sacramento River Estuary was studied in relation to food availability, i.e., plankton, from Jan to Nov 1976. The composition of the diet of N. mercedis varied in relation to mysid size and prey availability. Mysids exhibited strong positive selection for the large diatom prey species while 'avoiding' small diatom prey. Although diatoms were the most abundant prey identified from the guts of specimens of N. mercedis it was determined that predation on rotifers and copepods accounted for >80% of the energy consumed by other-than-juvenile mysids (7 mm in length). Juvenile mysids (3 mm in length) ingested rotifers when rotifers were abundant but were not found to consume copepods. Laboratory feeding experiments indicate a density-dependent feeding by N. mercedis on copepods: as copepod density increases mysid predation increases. N. mercedis is not a particularly active predator, capturing prey drawn into its feeding current but not actively pursuing prey. N. mercedis appears to feed continuously, with a peak in activity for mature mysids during darkness, a pattern not apparent in immature mysids. Consumption of the detritus was not considered significant. Although herbivory may be of direct importance during the spring diatom increase, carnivory was the major source of energy for N. mercedis in the Sacramento River during 1976.

Siegfried, C. A., M.E. Kopache, and A.W. Knight (1979). "The distribution and abundance of Neomysis mercedis in relation to the entrapment zone in the western Sacramento-San Joaquin Delta." Transactions of the American Fisheries Society 108: 262-268.
The distribution and abundance of the opossum shrimp, Neomysis mercedis, was studied in a portion of the upper San Francisco Bay estuary in 1976, the fourth-driest year on record. For much of 1976 the entrapment zone, an area of zero net horizontal flow, was located in the study area. Variations in the annual abundance of N. mercedis can be related to the location of the entrapment zone. In years of low flow, such as 1976, the entrapment zone is in the narrow channels of the upper estuary, thereby reducing habitat availability and, thus, the abundance of N. mercedis. Mysid population dynamics were highly correlated with reproduction, and fecundity with length, although the latter relationship changed seasonally. Juvenile mysids (3 mm long) tend to be higher in the water column during daylight than do mature mysids (7 mm long) leading to a geographic separation of these life stages. Estuarine hydraulics rather than salinity tolerance determines the distribution of N. mercedis in the study area.

Siegfried, C. A. (1980). "Seasonal abundance and distribution of Crangon franciscorum and Palaemon macrodactylus (Decapoda, Caridea) in the San Francisco Bay-Delta." Biological Bulletin 159: 177-192.
The seasonal abundance and distribution of the native C. franciscorum and the introduced P. macrodactylus in the channel areas of the San Francisco Bay Delta were studied from April 1977-Oct 1978. C. franciscorum reproduces from Dec-June and grows to a larger size than P. macrodactylus which reproduces from May-Sept. Length-weight and length-fecundity relationships differ significantly between the 2 species. Both are limited upstream by low salinities, few occurring at salinities <1 o/oo. The downstream distribution is related to prey availability, i.e., Neomys mercedis abundance. Indices of spatial overlap, or interspecies patchiness, indicate a high degree of overlap which varied seasonally and exhibited markedly different patterns in 1977 and 1978. Directional crowding (intraspecific patchiness) also differed between 1977 and 1978. P. macrodactylus appears more tolerant of varied environmental conditions than C. franciscorum , occurring in the same habitats and also in additional ones not utilized by C. franciscorum .

Siegfried, C. A. (1982). "Trophic relations of Crangon franciscorum Stimpson and Palaemon macrodactylus Rathbun: predation on the opossum shrimp, Neomysis mercedis Holmes." Hydrobiologia 89: 129-139.
C. franciscorum and P. macrodactylus are carnivorous shrimp in the Sacramento-San Joaquin River Delta. These shrimp prey primarily on the opossum shrimp, N. mercedis . Behavioral and morphological differences result in P. macrodactylus stomachs containing a greater number of prey, on the average, than C. franciscorum . Dietary overlap and similarity were high (> 80%) throughout the study. C. franciscorum is generally larger than P. macrodactylus and is able to ingest larger prey. This results in some size-related resource partitioning.

Siegfried, C. A. (1989). Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates (Pacific southwest). Crangonid shrimp, U.S. Fish and Wildlife Service: 27.
Species profiles are literature summaries of the taxonomy, morphology, range, life history, and environmental requirements of coastal aquatic species. They are prepared to assist in environmental impact assessments. Crangonid shrimp once were important in an export fishery but are now the basis of a bait fishery in San Francisco Bay. The shrimp are important components of the estuarine system, serving as an important food of almost all sport and commercial fishes of west coast estuaries. Spawning occurs in waters of > 15 ppt salinity. Ovigerous females are found year-round; abundance peaks in spring and summer in embayments and in winter offshore. Eggs hatch directly into planktonic zoea which require 30-40 days to develop into postlarvae. Larvae prefer surface waters, while postlarvae prefer bottom waters. Larvae are exposed to predominantly seaward currents and postlarvae to landward moving bottom currents. Juvenile crangonids are generally found in brackish to nearly fresh water but move to more saline waters as they mature. Crangonids are opportunistic predators of epibenthic and benthic forms. Annual abundance of crangonids in San Francisco Bay has been linked to the volume of freshwater flow to the estuary. Maintaining adequate freshwater flows to the estuary to ensure successful recruitment is vital to maintaining populations of this important component of the estuarine system. (Sponsored by National Wetlands Research Center, Slidell, LA., and Army Engineer Waterways Experiment Station, Vicksburg, MS, (USA).)

Siegfried, C. A., M. E. Kopache, et al. (1980). "The benthos of a portion of the Sacramento River (San Francisco Bay Estuary) during a dry year." Estuaries 3: 296-307.
Early in 1976 benthic studies were initiated in a 20 km long portion of the Western Sacramento-San Joaquin River Estuary. Water quality determinations indicated little vertical or horizontal differences in pH, temperature, or dissolved oxygen concentration within the study area. Low river outflows allowed the encroachment of seawater into the study area, an area normally exposed to fresh or slightly brackish water. The sediment composition changed dramatically at most stations during the year, being dominated by sands early in the year but by silts and clays in late summer. The shift in sediment composition was accompanied by an increase in grease and oil and metals content. The benthic community of the study area was generally dominated by Corbicula manilensis, Macoma balthica , oligochaetes, the amphipods Corophium stimpsoni and C. spinicorne , nematodes, and a spionid polychaete, Boccardia ligerica . These taxa comprised 98% on average of the total benthic macroinvertebrates collected at each study site. The benthic assemblages of each of the stations were generally very similar to one another. Faunal similarities and changes in benthos composition were related to substrate compositon and salinity incursion. In general, the upstream-channel stations had higher abundance of benthos than the other stations in the study area. Total standing crop peaked in June and was lowest in Nov. The most important factors controlling the size and species composition of the benthos of the study area are salinity and sediment composition.

Sigleo, A. C. and S. A. Macko (2002). "Carbon and Nitrogen Isotopes in Suspended Particles and Colloids, Chesapeake and San Francisco Estuaries, U.S.A." Estuarine, Coastal and Shelf Science 54(4): 701-711.
Chesapeake and San Francisco Bays, U.S.A., are both river dominated, temperate estuaries. The organic carbon and nitrogen isotopic compositions of the

suspended particles (greater than or equal to 0.4 mu m), however, show major differences for nitrogen and minor differences for carbon. In northern San Francisco Bay, the carbon isotope values averaged -26.2 plus or minus 0.2ppt delta super(13)C for suspended particles, and for Chesapeake Bay and the Potomac River, the average was -24.3 plus or minus 3.2ppt. The nitrogen isotope ratios (delta super(15)N) of suspended particles in northern San Francisco Bay in late summer were +0.9 plus or minus 0.4ppt, probably reflecting a nitrogen component from agricultural runoff. The values for Chesapeake Bay, and its subestuary, the Potomac River averaged +7.7 plus or minus 3.1ppt, with the highest values occurring during summer when the primary source of nitrogen originated from remineralized organic material. Carbon and nitrogen isotope values for colloids (less than or equal to 0.4 mu m) were 8.2 plus or minus 1.7 for nitrogen and -26.0 plus or minus 1.6 for carbon (n=17) throughout both estuaries and the Potomac river. Ultrafiltrates, collected after filtration and ultrafiltration, had delta super(15)N values of +7.3 plus or minus 0.3 and delta super(13)C values of -24.5 plus or minus 1.7. The similarity of isotopic values between suspended particles and colloids in winter samples suggested that these colloids were formed by desorption or dissociation from resuspended sediments and soils. Summer colloids in San Francisco Bay were uniformly heavier by 7ppt than suspended particles suggesting that the lighter isotope was selectively utilized by heterotrophs, leaving an isotopically heavy colloid residual.

Silva, P. C. (1979). The benthic algal flora of central San Francisco Bay. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 287-311.

The benthic algae of San Francisco Bay received only sporadic attention prior to 1968. The present account, based on a sustained program begun in 1968, is the first publication devoted entirely to the Bay flora.

The Bay offers a diversity of habitats ranging from moderately exposed to fully protected. The absence of fully exposed sites precludes those species that are restricted to such situations on the outer coast.

The benthic algae of the Bay constitute a large biomass, the bulk of which at any particular site is composed of an abundance of luxuriant plants belonging to only a few species. Those species found throughout the Bay flourish at least to the extent that they do on the outer coast. Cryptopleura violacea and Polyneura latissima are more abundant and luxuriant in the Bay than on the outer coast. On the other hand, many species that barely penetrate the Bay are less abundant and well developed than in physiographically similar sites on the outer coast.

The benthic algal flora of the Bay comprises about 170 specific and infraspecific taxa, a number that ranks the Bay, when considered a single locality, as fairly rich. The presence of at least 30 protected-water forms compensates for the absence of those outer-coast species that are unable to penetrate the Bay. The richest localities are Fort Point, Lime Point-Point Cavallo, and Point Blunt (Angel Island). Almost all major orders and families of the outer-coast flora of central California are represented in the Bay, although many common outer-coast species are absent. The major floristic component (at least 53%) is constituted by outer-coast cool-temperatate species endemic to Pacific North America. The second largest component (about 26%) is constituted by species with wide distributions, especially in the Northern Hemisphere. The warm-water element is negligible. There are

at least two recently introduced weeds (Sargassum muticum and Codium fragile subsp. tomentosoides).
Protected-water species are limited to mudflats, marshes, yacht harbors, and commercial port areas without regard to distance from the Golden Gate. Outercoast species, on the other hand, generally have ranges extending inward from the Golden Gate to varying distances. Groups of species characteristic of the upper, middle, and lower intertidal zones, respectively, on the outer coast all exhibit the same spectrum of ability to penetrate the Bay. The association of species characteristic of the sanded-in habitat on the outer coast exhibits this same spectrum.
The varying degree of penetration of the Bay by outer-coast species is in large part related to the salinity gradient extending from the Golden Gate to Point San Pablo, but precisely which aspects of salinity are limiting for individual species remains to be demonstrated. Wave action has a similarly oriented gradient and may restrict certain species to the extreme western part of the Bay, although most species occur in less exposed situations within the Bay than on the outer coast. Variation in temperature in the central Bay can be assumed to have a negligible effect on the distribution of outercoast species since the great majority have ranges extending over many degrees of latitude. The unusually low and high temperatures that occasionally obtain in marshes and mudflats, especially in the northern and southern reaches of the Bay, preclude all but eurythermal forms in those habitats.
The Bay offers a wide variety of substrates so that this factor is not limiting except in the case of the sanded-in habitat. Nutrients are maintained at a sufficiently high level to eliminate them as a factor affecting distribution of outer-coast species within the central Bay. Turbidity is probably not a factor in excluding outer-coast species from the central Bay, although heavy silting of the intertidal zone may have local adverse effects. As far as benthic algae are concerned, the central Bay, with the exception of the port area of San Francisco from Aquatic Park to the Bay Bridge and the Berkeley-Richmond shore, is relatively free from deleterious effects of urbanization

Silva, S., C. Kendall, M. Young, and A. Parker (2010). Isotopic trends of nutrient cycling and assimilation downstream of the Sacramento Regional Wastewater Treatment Plant. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Nutrient loading from anthropogenic sources in the San Francisco Bay and Delta is one of a number of potential sources of ecosystem disruption. Effluent from Sacramento Regional Wastewater Treatment Plant (SRWTP) is of concern due to its input of ammonium which may alter the aquatic food chain by favoring a different mix of aquatic primary producers and/or possibly reduce phytoplankton abundance through inhibition of nitrate assimilation. As part of two transects on the Sacramento River in March and April 2009, samples were collected for water chemistry and isotopes from the I-80 bridge at river mile 62.6 downriver to a point south of the Richmond Bridge at San Pablo Bay. Samples were analyzed for isotopes of ammonium, nitrate, particulate organic matter (POM), dissolved organic matter (DOM), and water isotopes. These analyses, along with conventional water chemistry, were used to assess the fate of nutrients added by SRWTP and the response of plankton as represented by POM. d15N of NH4 showed a dramatic increase downstream as [NH4] decreased and [NO3] increased due to nitrification, providing a distinct isotopic

signature for SRWTP-derived NH4. The d15N and d13C of the POM (mostly algae) show distinct downstream changes due to uptake of NH4. The isotopic and concentration data from both the March and April transects suggest a change from NO3 to NH4 assimilation as phytoplankton pass through the zone of elevated NH4 concentration below SRWTP and a return to nitrate assimilation between 30 and 60 miles (April and March data respectively) below SRWTP. The isotopic trends reflect the extent and progress of both nitrification and assimilation downstream of SRWTP.

Silver, E., J. Kaslow, et al. (2007). "Fish consumption and advisory awareness among low-income women in California's Sacramento-San Joaquin Delta." Environmental Research 104(3): 410-419.

Fishing is a culturally important activity to the ethnically diverse population living in California's Sacramento-San Joaquin Delta. Due to runoff from abandoned gold mines, certain Delta fish are contaminated with methylmercury, a neurodevelopmental toxin. A state health advisory recommends limited consumption of certain Delta fish, to be followed in conjunction with a federal advisory for commercial and sport fish. We conducted a survey of low-income women at a Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) clinic, to characterize commercial and sport fish consumption patterns and advisory awareness. Ninety-five percent of women consumed commercial fish. Thirty-two percent consumed sport fish; this proportion was much higher in Hmong (86%) and Cambodian (75%) women. Ninety-nine percent of sport fish consumers also consumed commercial fish. The overall fish consumption rate among consumers was 27.9g/day (geometric mean, past 30 days, cooked portion); commercial and sport fish consumption rates were 26.3 and 10.5g/day, respectively. We found ethnic differences in overall fish consumption rates, which were highest in African Americans (41.2g/day) and Asians (35.6g/day), particularly Vietnamese and Cambodians. Pregnant women ate less fish overall than other women (16.8 vs. 30.0g/day, p=0.0001), as did women who demonstrated specific advisory awareness (23.3 vs. 30.3g/day, p=0.02). Twenty-nine percent of all women exceeded federal fish consumption advisory limits. These results highlight the need for culturally and linguistically appropriate interventions that address both commercial and sport fish consumption.

Simenstad, C. A., J. Toft, H. Higgins, J. Cordell, M.Orr, P. Williams, L. Grimaldo, Z. Hymanson, and D. Reed (2000). Preliminary Report: Sacramento/San Joaquin Delta Breached Levee Wetland Study (BREACH). Seattle, School of Fisheries, University of Washington: 51 pp.

Sing, P., S. Ma, L. Andes, F. Wu, W. Brostoff, and M.L. MacWilliams (2010). Hydrodynamic and salinity modeling of the Sacramento River Deep Water Ship Channel. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The U.S. Army Corps of Engineers is conducting a study of deepening the Sacramento River Deep Water Ship Channel (SRDWSC) from 30 ft MLLW to the authorized depth of 35 ft MLLW. The SRDWSC is a 46.5 mile long channel from New York Slough to the Port of West Sacramento. Changes in salinity and hydrodynamics are important issues in the potential deepening of the SRDWSC. UnTRIM, a three-dimensional hydrodynamic and salinity numerical model, was selected to capture the physics associated with downstream tidal forcing, upstream freshwater flow, X2, and density gradient induced gravitational circulation of the existing channel and future conditions with and without channel deepening. The computation domain covers the Sacramento-San Joaquin Delta and the San Francisco Bay. The future condition simulations include a sea level rise of 0.6 m, and account for the operational response to both future water demands and the actions required under most recent biological opinions. Predicted time series data for water elevation, velocity, and salinity were analyzed to evaluate potential project impacts. Model results show no significant change in water surface elevation or tidal flows for existing and future conditions with the deepening of the channel. However, results indicate slight decreases in water surface elevation in narrow reaches during flood conditions due to increased cross sectional areas. The model predicts salinity increases of up to 0.15 psu during some periods for existing and future conditions for channel deepening. The maximum predicted increase in X2 measured for the deepened channel is 2.5 km, with more typical predicted X2 increases of 1.0 to 1.5 km during late fall.

The deepening of the SRDWSC does not have an impact on salinity during periods when X2 is less than 75 km. Model predictions will aid decision makers in understanding potential hydrodynamic and water quality impacts from channel deepening.

Sitts, R. M. and A. W. Knight (1979). "Predation by the estuarine shrimps Crangon franciscorum Stimpson and Palaemon macrodactylus Rathbun." Biological Bulletin 156: 356-368.

Foregut contents from 352 specimens of C. franciscorum and 193 specimens of P. macrodactylus collected over six diel cycles in 1976 were itemized. C. franciscorum and P. macrodactylus are mainly carnivorus. Animal material always exceeded plant fragments in frequency of occurrence in foreguts, being respectively 46 to 86% and 7 to 61% in C. franciscorum and 74 to 92% and 0 to 59% in P. macrodactylus . The most frequent prey item identifiable in both predators was Neomysis mercedis . Both predators selected for N. mercedis of intermediate lengths (5 to 9 nm), and selected against those 2 mm or >10 mm long. Day and night differences in the number of individuals of N. mercedis per foregut were significant only for C. franciscorum , and then only in late September and late November, with greater means at night in each case. The percentages of N. mercedis standing crops consumed daily by V. franciscorum and P. macrodactylus respectively, ranged from 0.1 to 6.2% and 0.0 to 4.8% in terms of individuals, and from 0.1 to 5.1% and 0.0 to 3.7% for biomass. The percent of their respective population biomasses that specimens of C. franciscorum and P. macrodactylus respectively consumed daily as N. mercedis ranged from 1 to 3% and 1 to 4%. Similarities between these predators suggest the possibility of competition.

Skinner, J. E. (1962). Fish and wildlife resources of the San Francisco Bay area. Sacramento, California Department of Fish and Game Water Projects Report No. 1: 226.

Skinner, J. E. (1973). Evaluation testing program report for Delta Fish Protective Facility, State Water Facilities, California Aqueduct, North San Joaquin Division Memorandum Report. Califoria Resources Agency. 121 pp.

Slater, S. (2010). Effects of formalin preservation and delayed measurements on length, weight, and condition estimates of longfin smelt, striped bass, and threadfin shad. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Slaughter, A., and W.J. Kimmerer (2010). Abundance, composition, feeding, and reproductive rates of key copepod species in the food-limited Low Salinity Zone of the San Francisco Estuary. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The San Francisco Estuary (SFE) serves as important habitat for numerous fish species. Recent declines in the abundance of several pelagic fish species in the upper estuary have prompted further investigation into the foodweb of the low salinity zone (LSZ). The LSZ is rearing habitat for delta smelt and other fishes, and a region of low primary productivity and many introduced copepod species. We measured copepod abundance, species composition, feeding, and reproductive rates in the LSZ during spring-summer of 2006-2008. Eurytemora affinis was the most abundant copepod present in the spring (max. abundance ~15,000 indiv m-3) after which its numbers declined and other copepods (Pseudodiaptomus forbesi,Limnoithona tetraspina, and Acartiella sinensis) became the dominant taxa in the summer (~12,000, 91,000 and 3,000 indiv m-3, respectively). Pseudodiaptomus forbesi, a calanoid copepod introduced to SFE in 1987, is an important food source for young pelagic fishes although its numbers have steadily declined in recent years. Limnoithona tetraspina has become and remains the numerically dominant copepod in the LSZ since its introduction in late 1993. Finally, A. sinensis(also introduced in 1993) is a predator that consumes Limnoithona nauplii. Phytoplankton cells were generally smaller than two decades ago, resulting in a less efficient foodweb as copepods consume microzooplankton rather than large diatoms. The dominant copepod taxa in the LSZ have very low reproductive rates (2-3 eggs female-1 d-1 for Pseudodiaptomus forbesi, 0-7 eggs female-1 d-1 for Eurytemora affinis) compared to taxa in other areas of the SFE (e.g., up to 30 eggs female-1 d-1 for Acartia sp.), suggesting that food limitation plays a significant role in the function of the LSZ foodweb and

possibly in declines of pelagic fish.

Smalling, K., J. Orlando, and K. Kuivila (2010). Changing agricultural pesticide use and the implications to native fish in the Yolo Bypass. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

A variety of different pesticides including organophosphate and pyrethroid insecticides as well as several newly registered fungicides are used in the productive agricultural areas surrounding the Yolo Bypass. This leveed flood control basin in Northern California provides key migration corridors and important rearing/spawning grounds for native fish. In 2004-2005 a study was conducted to evaluate three potential sources of agricultural pesticides to the Yolo Bypass that could potentially impact critical life stages of native fish. Surface water, bed and suspended sediments were collected to assess the direct/indirect inputs of pesticides to the Bypass during high and low flow events. A variety of different current-use pesticides, including several herbicides (hexazinone and simazine) were detected frequently in surface water while the more hydrophobic pyrethroid insecticides (bifenthrin, cyhalothrin and t-fluvalinate) were detected in sediment at relatively low concentrations (<10 ppb). The pesticides detected in sediment and surface water varied by site and were correlated with agricultural application in each watershed. Agriculture and associated pesticide use in the watersheds surrounding the Bypass continues to change from year to year. Sensitive, comprehensive and robust laboratory methods are currently being developed to adapt to shifts in pesticide use patterns. For example, fungicide use, particularly on rice and almonds, has increased and methods have been developed to effectively analyze these newly registered compounds. Between 2004 and 2008 organophosphate use decreased while use of two pyrethroids bifenthin and esfenvalerate has increased. Adapting laboratory methods and monitoring efforts to reflect changing pesticide use is necessary to update our state of knowledge on the fate and transport of pesticides within the Yolo Bypass. This information is critical for resource managers and fisheries biologists to assess the potential risks of multiple stressors as well as long-term contaminant exposure to fish.

Smalling, K. L., J. L. Orlando, et al. (2007). "Occurrence of Pesticides in Water, Sediment, and Soil from the Yolo Bypass, California." San Francisco Estuary and Watershed Science 5(1): Article 2.

The objective of this study was to evaluate the potential sources of pesticides to the Yolo Bypass, including those that could potentially impact critical life stages of resident fish. To assess direct inputs during inundation, pesticide concentrations were analyzed in water and suspended and bed sediment samples collected from source watersheds during high-flow events. To understand inputs from direct application on fields, pesticides were also measured in soils collected from several sites within the Bypass. Thirteen current-use pesticides were detected in water samples collected in 2004 with the highest pesticide concentrations observed at the input sites to the Bypass during high-flow. Hexazinone and simazine were detected at all sites and at some of the highest concentrations. In bed and suspended sediments collected in 2004 and 2005, thirteen current-use pesticides were detected along with DDT and its metabolites. Trifluralin, DDE, and DDT were highest in the bed sediments, whereas oxyfluorfen and thiobencarb were highest in the suspended sediments. With the exception of the three organochlorine insecticides, suspended sediments had higher pesticide concentrations compared to bed sediments, indicating the potential for pesticide transport especially during high-flow events. Soil samples were dominated by DDT and its degradates but also contained a variety of current-use pesticides typically at lower concentrations. The types of pesticides detected in water and sediments were correlated with agricultural application in each watershed.

Understanding the distribution of pesticides between the water and sediment is important in assessing their fate and transport within the Bypass, and in evaluating the exposure and potential effects to resident fish.

Smallwood, K. S., B. Wilcox, R. Leidy, and K. Yarris (1998). "Indicators assessment for habitat conservation plan of Yolo County, California, USA." Environmental

Management 22(6): 947-958.
Whereas habitat conservation plans (HCPs) have been intended to provide comprehensive environmental mitigation for multiple species, they often narrow in focus to one species and either one mitigation site or unspecified sites. We developed an indicators framework from which to rate land units for their ecological integrity, collateral values (nonbiological qualities that can improve conservation), and restoration and conservation opportunities. The ratings of land units were guided by the tenets of conservation biology and principles of landscape and ecosystem ecology, and they were made using existing physical and floral information managed on a GIS. As an example of how the indicators approach can be used for HCPs, the 29 legally rare species targeted by the Yolo County HCP were each associated with vegetation complexes and agricultural crops, the maps of which were used for rating some of the landscape indices. The ratings were mapped so that mitigation can be directed to the places on the landscape where the legally rare species should benefit most from conservation practices. The most highly rated land units for conservation opportunity occurred along streams and sloughs, especially where they emerged from the foothills and entered the Central Valley and where the two largest creeks intersected the Sacramento River flood basin. We recommend that priority be given to mitigation or conservation at the most highly rated land units. The indices were easy to measure and can be used with other tools to monitor the mitigation success. The indicators framework can be applied to other large-area planning efforts with some modifications.

Smith, D. R., M. D. Stephenson, et al. (1986). "Trace metals in mussels transplanted to San Francisco Bay." Environmental Toxicology and Chemistry 5(2): 129-138.
Mussels (Mytilus californianus) transplanted to San Francisco Bay exhibited elevated trace metal concentrations compared with those in other mussel watch studies on the west coast of the United States. The highest concentrations of Ag, Cu, Hg., Mn, Pb and Zn were at the South Bay stations, and often in the Redwood Creek area. Ag and Hg concentrations were linearly correlated with station distance from the North Bay (San Pablo Bay), indicating that the South Bay is a major reservoir of these pollutants within San Francisco Bay.

Smith, G. E. (1978). "An evaluation of disk-dangler tag shedding by striped bass (Morone saxatilis) in the Sacramento-San Joaquin Estuary." California Fish and Game 64: 93-97.
A total of 1,162 striped bass (M. saxatilis) were tagged with disk-dangler tags below the anterior and posterior dorsal fins. Tags from 337 of these fish were returned within 7 years. Tags attached below the anterior fin, the normal tagging location, experienced no immediate losses and annual losses of 4 . 9% for 4 years thereafter. Tags below the posterior fin experienced 5 . 6% immediate and 8 . 4% annual losses.

Smith, G. J. and A. R. Flegal (1993). "Silver in San Francisco Bay Estuarine Waters." Estuaries 16(3A): 547-558.
Spatial gradients of silver concentrations in the surface waters of San Francisco Bay reveal substantial anthropogenic perturbations of the biogeochemical cycle of the element throughout the estuarine system. The most pronounced perturbations are in the south bay, where dissolved (<0.45 mu m) silver concentrations are as high as 250 pM. This is more than one order-of-magnitude above baseline concentrations in the northern reach of the estuary (6 pM) and approximately two orders-of-magnitude above natural concentrations in adjacent coastal waters (3 pM). The excess silver is primarily attributed to wastewater discharges of industrial silver to the estuary on the order of 20 kg/d. The contamination is most evident in the south bay, where wastewater discharges of silver are on the order of 10 kg/d and natural freshwater discharges are relatively insignificant. The limited amount of freshwater flushing in the south bay was exacerbated by persistent drought conditions during the study period. This extended the hydraulic residence time in the south bay (greater than or equal to 160 d), and revealed the apparent seasonal benthic fluxes of silver from anthropogenically contaminated sediments. These were conservatively estimated to average) 16 nmol m super(-2)/d in the south bay, which is sufficient to replace all of the dissolved silver in the south bay within 22 d. Benthic fluxes of silver throughout the estuary

were estimated to average) 11 nmol m super(-2)/d, with an annual input of approximately 540 kg/yr of silver to the system. This dwarfs the annual fluvial input of silver during the study period (12 kg yr super(-1)), and is equivalent to approximately 10% of the annual anthropogenic input of silver to the estuary (3,700-7,200 kg/yr). It is further speculated that benthic fluxes of silver may be greater than or equal to waste water fluxes of silver during periods of intense diagenic remobilization. However, all inputs of dissolved silver to the estuary are efficiently sorbed by suspended particulates, as evidenced by the relatively constant conditional distribution coefficient for silver throughout the estuary (K sub(d)) 10 super(5)).

Smith, L., L.A. Brand, N. Athearn, and J.Y. Takekawa (2010). Bathymetric surveys of Ponds 3, 4, and 5 in the Napa-Sonoma Marshes. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The Napa-Sonoma Marshes managed by the California Department of Fish and Game in the North San Francisco Bay consist of several large former salt production ponds that are being restored as salt marsh. The restoration process was initiated in 2002 with a breach in Pond 3 and subsequent breaching of Ponds 4 and 5 in 2006. These ponds had subsided and require extensive sedimentation to occur before a suitable elevation is reached for salt marsh plant colonization. We used a shallow-water bathymetric survey system consisting of a shallow-water transducer and a Real-Time Kinematics GPS to map the elevation of the ponds and to assess changes in sedimentation. We mapped Pond 3 in 2005 and 2008, Pond 4 in 2008, and Pond 5 in 2009. We created digital elevation models in NAVD88 meters using Inverse Distance Weighting with barrier polylines in ArcGIS 9.3. The mean pond elevation of Pond 3 in 2005 was 0.96m ± 0.19 SD. In 2008-2009, mean pond elevations were 1.05 m ± 0.25 SD in Pond 3, 0.81 m ± 0.26 SD in Pond 4, and 0.84 m ± 0.24 SD in Pond 5. Pond 3 had an average increase of 0.10 m of sediment across the four years. Specific regions within all 3 ponds and particularly in Pond 3 have an elevation substantially higher than the mean and support colonizing Spartina foliosa. The rate of increase in elevation has been comparable with other sites around the bay, and indicates likely success of early restoration to tidal marsh within this system.

Smith, L., and P. Hrodey (2010). The recipe for success - what makes Liberty Island so attractive to native fish? 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Tidally influenced, freshwater marsh habitat is an important component for the early life stages of many fishes found within the Sacramento - San Joaquin River Delta. Amid possible changes in water development, land-use planning, and levee deterioration this once limited habitat may become more available to native fish species, and in particular, Delta smelt Hypomesus transpacificus. Liberty Island is a former artificial island which has been undergoing passive restoration after its levees breached in 1997. The Stockton office of the U.S. Fish and Wildlife Service has been involved with monitoring the fish communities utilizing Liberty Island habitats since the early 2000s. The results of our sampling efforts from 2002 - 2005 indicate that there were significant temporal differences in habitat use by native and non-native fish species of varying life stages. Delta smelt were collected within the island on a year-round basis, representing every significant life stage other than egg. When compared to adjacent Sacramento River beach seine locations, Delta smelt relative abundances were significantly lower in Liberty Island; however, their relative growth rates were significantly higher. This presentation will re-examine our previous sampling efforts in Liberty Island along with highlighting the beach seine and egg and larval trawling that we re-initiated in January 2010. It is not yet known what physio-chemical properties of Liberty Island habitats are attractive to Delta smelt and other native species of concern such as Chinook salmon Oncorhynchus tshawytscha and Splittail Pogonichthys macrolepidotus. Based on these data and our involvement in the Breach III study we hope to gain a better understanding of the habitat use and feeding habits of native fishes within Liberty Island. Having these questions answered would go a long way towards informing future restoration efforts in the Cache Slough and Yolo Bypass areas.

Smith, L. (2010). Trends in abundance and size of delta smelt and longfin smelt and the influence of environmental conditions. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Trends in relative abundance and size of Delta smelt Hypomesus transpacificus and longfin smelt Spirinchus thaleichthys in response to environmental conditions may provide insight into the ecological state of the Sacramento-San Joaquin Estuary with respect to supporting these fish species. Identifying the response of a species to changes in environmental conditions is an important element in the effective management of the estuary. Delta smelt Hypomesus transpacificus (DSM) and longfin smelt (LFS) Spirinchus thaleichthys populations are at low levels in the Sacramento-San Joaquin Estuary. The decline of these species has been associated with environmental conditions. For this study, I used an existing long term monitoring data set to illustrate trends in size (measured to fork length, FL) and relative abundance (measured as catch-per-unit effort, CPUE) of DSM and LFS with four environmental factors: Secchi depth (water clarity), water temperature, discharge, and X2 (2 ppt isohaline position). The data for this study were collected weekly from 1996 – 2008 with a mid-water trawl near Chipps Island. I used Pearson’s correlation coefficients to assess the relation among environmental factors and CPUE and FL of DSM and LFS. Other studies indicate environmental factors, such as temperature and water clarity, can influence DSM and LFS abundance. I found no statistically significant correlations among abundance or size of DSM and LFS with temperature, discharge, or X2. Secchi depth was negatively correlated with CPUE for DSM and all ages of LFS. Relative abundance of DSM and LFS declined throughout the sampling period, which is consistent with other studies that describe the Pelagic Organism Decline. The negative influence of Secchi depth on our catches of DSM and LFS suggests that these species may prefer turbid conditions. The negative correlation could be a function of population responses to water clarity, but may be a function of habitat use and gear efficiency. This analysis provides an example of how existing monitoring data can provide valuable insights into the ecology of non-targeted species.

Smith, L. H. (1987). A review of circulation and mixing studies of San Francisco Bay, California. U.S. Geological Survey Circular. 1015: 38 pp.

A description of the major characteristics and remaining unknowns of circulation and mixing in San Francisco Bay has been constructed from a review of published studies. From a broad perspective San Francisco Bay is an ocean-river mixing zone with a seaward flow equal to the sum of the river inflows less evaporation. Understanding of circulation and mixing within the bay requires quantification of freshwater inflows and ocean-bay exchanges, characterization of source-water variations, and separation of the within-bay components of circulation and mixing processes. Description of net circulation and mixing over a few days to a few months illustrates best the interactions of major components. Quantification of tidal circulation and mixing is also necessary because net circulation and mixing contain a large tide-induced component, and because tidal variations are dominant in measurements of stage, currents, and salinity.

The discharge of the Sacramento-San Joaquin Delta into Suisun Bay is approximately 90 percent of the freshwater inflow to San Francisco Bay. Annual delta discharge is characterized by a winter season of high runoff and a summer season of low runoff. For the period 1956 to 1985 the mean of monthly discharges exceeded 1,000 cubic meters per second (35,000 cubic feet per second) for the months of December through April, whereas for July through October, it was less than 400 cubic meters per second (14,000 cubic feet per second). The months of November, May, and June commonly were transition months between these seasons. Large year-to-year deviations from this annual pattern have occurred frequently.

Much less is known about the ocean-bay exchange process. Net exchanges depend on net seaward flow in the bay, tidal amplitude, and longshore coastal currents, but exchanges have not yet been measured successfully. Source-water variations are ignored by limiting discussion of mixing to salinity.

The bay is composed of a northern reach, which is strongly influenced by delta discharge, and South Bay, a tributary estuary which responds to conditions in

Central Bay. In the northern reach net circulation is characterized by the river-induced seaward, flow and a resulting gravitational circulation in the channels, and by a tide- and wind-induced net horizontal circulation. A surface layer of relatively fresh water in Central Bay generated by high delta discharges can induce gravitational circulation in South Bay. During low delta discharges South Bay has nearly the same salinity as Central Bay and is characterized by tide- and wind-induced net horizontal circulation.

Several factors control the patterns of circulation and mixing in San Francisco Bay. Viewing circulation and mixing over different time-periods and at different geographic scales causes the influences of different factors to be emphasized. The exchange between the bay and coastal ocean and freshwater inflows determine the year-to-year behavior of San Francisco Bay as a freshwater-saltwater mixing zone. Within the bay, exchanges between the embayments control variations over a season. Circulation and mixing patterns within the embayments and the magnitude of river-induced seaward flow influence the between-bay exchanges. The within-bay patterns are in turn determined by tides, winds, and freshwater inflows.

Because freshwater inflow is the only factor that can be managed, a major study focus is estimation of inflow-related effects. Most questions relate to the patterns of freshwater inflow necessary to protect valuable resources whose welfare is dependent on conditions in the bay. Among the important questions being addressed are: --What quantity of freshwater inflow is necessary to prevent salt intrusion into the Sacramento-San Joaquin Delta, and what salinity distributions in the bay would result from various inflow patterns? --What quantity of freshwater inflow is sufficient to flush pollutants through the bay?

Knowledge of circulation and mixing in the bay is necessary to address these questions

Smith, L. H. and R. T. Cheng (1987). "Tidal and tidally averaged circulation characteristics of Suisun Bay, California." Water Resources Research 23: 143-155.

Smith, P. E., R. N. Oltmann, et al. (1995). Summary report on the interagency hydrodynamic study of the San Francisco Bay-Delta estuary, California. Sacramento, CA, Interagency Ecological Preogram for the Sacramento-San Joaquin Estuary. Technical Report 45.

Smith, S. E. and S. Kato (1979). The fisheries of San Francisco Bay: past, present, and future. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 445-468.

Smith, S. V. and J. T. Hollibaugh (2000). Water, salt, and nutrient exchanges in San Francisco Bay. Sacramento CA, Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 66.

Smith, S. V. and J. T. Hollibaugh (2006). "Water, salt, and nutrient exchanges in San Francisco Bay." Limnology and Oceanography 51(1): 504-517.
We constructed water, salt, and nutrient budgets for San Francisco Bay and used them to analyze the net biogeochemical performance of the bay. The bay was subdivided into three sectors, North, Central, and South Bay, with the Central Bay serving as a proxy for the oceanic end member. Separate budgets were constructed for the wet (October-March) and dry (April-October) seasons of each year for 6 yr (1990-1995). This period of record contained 2 yr of above normal runoff (1993, 1995) and 4 yr of below average runoff. Effluent from sewage treatment plants accounts for approximately 50% of the nutrient loading to the bay in winter and 80% of the summer loading. Both arms of the bay were apparently net heterotrophic during the winter, with this signal being strongest during the wet winters of 1993 and 1995. We conclude that overall the bay is slightly net autotrophic (production of new organic matter in the bay by plant growth exceeds respiratory demands); however, this varies seasonally (strongest in summer) and is complicated by the possibility of significant abiotic P adsorption in the North Bay.

Sobcrak, W. V., J.E. Cloern, B.E. Cole, T.S. Schraga, and A. Arnsberg (2005). "Deritus fuels ecosystem metabolism but not metazoan food webs in San Francisco Estuary's freshwater Delta." Estuaries 28(1): 14.
Detritus from terrestrial ecosystems is the major source of organic matter in many streams, rivers, and
estuaries, yet the role of detritus in supporting pelagic food webs is debated. We examined the importance of detritus
to secondary productivity in the Sacramento and San Joaquin River Delta (California, United States), a large complex
of tidal freshwater habitats. The Delta ecosystem has low primary productivity but large detrital inputs, so we hypothesized
that detritus is the primary energy source fueling production in pelagic food webs.We assessed the sources, quantity,
composition, and bioavailability of organic matter among a diversity of habitats (e.g., marsh sloughs, floodplains, tidal
lakes, and deep river channels) over two years to test this hypothesis. Our results support the emerging principle that
detritus dominates riverine and estuarine organic matter supply and supports the majority of ecosystem metabolism. Yet
in contrast to prevailing ideas, we found that detritus was weakly coupled to the Delta's pelagic food web. Results from
independent approaches showed that phytoplankton production was the dominant source of organic matter for the
Delta's pelagic food web, even though primary production accounts for a small fraction of the Delta's organic matter
supply. If these results are general, they suggest that the value of organic matter to higher trophic levels, including
species targeted by programs of ecosystem restoration, is a function of phytoplankton production.

Sobczak, W. V., J.E. Cloern, A.D. Jassby, and A.B. Muller-Solger (2002). "Bioavailability of organic matter in a highly disturbed estuary: The role of detrital and algal resources." Proceedings of the National Academy of Sciences 99(12): 8101-8105.
The importance of algal and detrital food supplies to the planktonic food web of a highly disturbed, estuarine ecosystem was evaluated in response to declining zooplankton and fish populations. We assessed organic matter bioavailability among a diversity of habitats and hydrologic inputs over 2 years in San Francisco Estuary's Sacramento-San Joaquin River Delta. Results show that bioavailable dissolved organic carbon from external riverine sources supports a large component of ecosystem metabolism. However, bioavailable particulate organic carbon derived primarily from internal phytoplankton production is the dominant food supply to the planktonic food web. The relative importance of phytoplankton as a food source is surprising because phytoplankton production is a small component of the ecosystem's organic-matter mass balance. Our results indicate that management plans aimed at modifying the supply of organic matter to riverine, estuarine, and coastal food webs need to incorporate the potentially wide nutritional range represented by different organic matter sources.

Solow, A. R. and C. J. Costello (2004). "Estimating the rate of species introductions from the discovery record." Ecology 85(7): 1822-1825.
The discovery record of introduced species reflects a combination of the introduction process and the discovery process. For this reason, the discovery record does not provide a direct proxy for the record of introductions. We describe a general method for estimating the rate of introductions from the discovery record. The method is based on a statistical model of the discovery record that includes both the introduction and discovery processes. The method is illustrated using the discovery record of introduced species in the San Francisco estuary (California, USA). The estimated mean rate of introductions increases from 0.3 introductions in, 1850 to 2.3 introductions in 1995.

Sommer, T., K. Reece, F. Feyrer, R. Baxter, and M. Baerwald (2010). Splilttail Persistence in the Petaluma River. IEP Newsletter. 23: 2.

Sommer, T., F. Mejia, et al. (2011). "Long-Term Shifts in the Lateral Distribution of Age-0 Striped Bass in the San Francisco Estuary." Transactions of the American Fisheries Society 140(6): 1451-1459.

Sommer, T., F. H. Mejia, et al. (2011). "The Spawning Migration of Delta Smelt in the Upper San Francisco Estuary." San Francisco Estuary and Watershed Science 9(2).

Sommer, T. a. F. M. (2013). "A Place to Call Home: A Synthesis of Delta Smelt Habitat in the Upper San Francisco Estuary." San Francisco Estuary and Watershed Science 11(2): 27.

We used a combination of published literature and field survey data to synthesize the available
information about habitat use by delta smelt Hypomesus transpacificus, a declining native species
in the San Francisco Estuary. Delta smelt habitat ranges from San Pablo and Suisun bays to
their freshwater tributaries, including the Sacramento and San Joaquin rivers. In recent years,
substantial numbers of delta smelt have colonized habitat in Liberty Island, a north Delta area that
flooded in 1997. The species has a more upstream distribution during spawning as opposed to
juvenile rearing periods. Post-larvae and juveniles tend to have a more downstream distribution
during wetter years. Delta smelt are most common in low-salinity habitat (<6 psu) with high
turbidities (>12 NTU) and moderate temperatures (7 °C to 25 °C). They do not appear to have
strong substrate preferences, but sandy shoals are important for spawning in other osmerids. The
evidence to date suggests that they generally require at least some tidal flow in their habitats.
Delta smelt also occur in a wide range of channel sizes, although they seem to be rarer in small
channels (<15 m wide). Nonetheless, there is some evidence that open water adjacent to habitats
with long water-residence times (e.g. tidal marsh, shoal, low-order channels) may be favorable.
Other desirable features of delta smelt habitat include high calanoid copepod densities and low
levels of submerged aquatic vegetation (SAV) and the toxic algae Microcystis. Although enough is
known to plan for large-scale pilot habitat projects, these efforts are vulnerable to several factors,
most notably climate change, which will change salinity regimes and increase the occurrence
of lethal temperatures. We recommend restoration of multiple geographical regions and habitats
coupled with extensive monitoring and adaptive management. An overall emphasis on ecosystem
processes rather than specific habitat features is also likely to be most effective for recovery of
the species.

Sommer, T. R., R. Baxter, and B. Herbold. (1997). "Resilience of splittail in the Sacramento-San Joaquin Estuary." Transactions of the American Fisheries Society 126: 961-976.

Splittail Pogonichthys macrolepidotus, an endemic cyprinid of the Sacramento-San Joaquin estuary, has been proposed for listing as threatened under the U.S. Endangered Species Act. Almost continuous low outflow conditions in the estuary from 1987 to 1994 led to reduced abundance of young splittails, but adult abundance did not decline consistently except in the downstream portion of the

species' range. This range had decreased primarily as a result of historical levee and dam construction but did not appear to have changed substantially in the past 20 years. The distribution of young splittails appears to be relatively plastic on an interannual basis. Evidence of resilience of the species was seen when high freshwater outflows in extremely wet years (such as 1982, 1983, 1986, and 1995) resulted in high numbers of young splittails. Splittail year-class strength was positively related to freshwater outflow during the spawning season. High outflow inundates the floodplain, which provides spawning, rearing, and foraging habitat. The relatively long life span, high reproductive capacity, and broad environmental tolerances of splittails are contrasted with delta smelt Hypomesus transpacificus and longfin smelt Spirinchus thaleichthys, other native species of special concern in the system.

Sommer, T. R., M.L. Nobriga, and B. Harrell (1998). Results of 1997 Yolo Bypass studies. IEP Newsletter. 11: 39-42.

Sommer, T. R., M.L. Nobriga, B. Harrell, W. Batham, R. Kurth, and W.J. Kimmerer (2000). Floodplain rearing may enhance growth and survival of juvenile chinook salmon in the Sacramento River. IEP Newsletter. 13: 26-30.

Sommer, T. R., B. Harrell, M.L. Nobriga, R. Brown, P.B. Moyle, W. Kimmerer, and L. Schemel. (2001). "California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture." Fisheries 26(8): 6-16.

Unlike conventional flood control systems that frequently isolate rivers from ecologically- essential floodplain habitat, California's Yolo Bypass has been engineered to allow Sacramento Valley floodwaters to inundate a broad floodplain. From a flood control standpoint, the 24,000 ha leveed floodplain has been exceptionally successful based on its ability to convey up to 80% of the flow of the Sacramento River basin during high water events. Agricultural lands and seasonal and permanent wetlands within the bypass provide key habitat for waterfowl migrating through the Pacific Flyway. Our field studies demonstrate that the bypass seasonally supports 42 fish species, 15 of which are native. The floodplain appears to be particularly valuable spawning and rearing habitat for the splittail (Pogonichthys macrolepidotus), a federally-listed cyprinid, and for young chinook salmon (Oncorhynchus tshawytscha), which use the Yolo Bypass as a nursery area. The system may also be an important source to the downstream food web of the San Francisco Estuary as a result of enhanced production of phytoplankton and detrital material. These results suggest that alternative flood control systems can be designed without eliminating floodplain function and processes, key goals of the 1996 Draft AFS Floodplain Management Position Statement.

Sommer, T. R., D.R. McEwan, and R. Brown. (2001). Factors affecting chinook salmon spawning in the lower Feather River. Contributions to the biology of Central Valley salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 1: 269-297.

We review the status of chinook salmon in the lower Feather River and examine factors affecting chinook salmon spawning since the construction of Oroville Dam. Spawning occurred in depths from 0.4 to 4 ft with the central 50% of observations in the 1.6 to 2.6 ft range. Depth used was slightly higher at increased flows. Velocities of 0.4 to 4.8 ft/s (central 50% = 1.5 to 2.7 ft/s) were used at all flows. Redds were constructed in substrate containing less than 60% fines in 0.2- to 1-inch to 6- to 9-inch gravel size classes. Redd surveys showed that spawning occurred in twice as much area below Thermalito Afterbay Outlet than the low flow channel (LFC). However, in most recent years, about 75% of fish spawned in the LFC. Superimposition indices calculated from these results suggest that there was insufficient spawning area in the LFC to support the number of spawning pairs, but adequate area below Thermalito Afterbay Outlet. Spawning activity was highest in the upper three miles of the LFC, whereas spawning area was relatively evenly distributed below Thermalito Afterbay Outlet. Historical results suggest superimposition significantly reduces egg survival. Statistical analysis of historical data showed that there has been a highly significant increase in the number of salmon spawning in the LFC. In-channel escapement explained a significant

additional portion of the variability in spawning distribution. The significant increase in the proportion of spawners using the LFC over time may be at least partially attributable to an increasing proportion of river flow from this channel. Substrate composition based on Wolman counts and bulk samples do not explain trends in spawning distribution as LFC gravel has become progressively armored over the past 16 years, whereas downstream substrate composition has not changed detectably. Temperature trends were not significantly correlated with spawning distribution. We hypothesize that hatchery stocking location and genetic introgression between fall-run and spring-run chinook stocks also account for spawning activity in the LFC. Spawning simulations using an egg production model based on these statistical analyses yielded very different results than a PHABSIM instream flow model.

Sommer, T. R., W.C. Harrell, M.L. Nobriga, and R. Kurth (2001). Floodplain as habitat for native fish: Lessons from California's Yolo Bypass. 2001 Riparian Habitat and Floodplains Conference Proceedings: California riparian systems: Processes and floodplain management, ecology, and restoration, Riparian Habitat Joint Venture, Sacramento, California

In the following paper we describe the Yolo Bypass, the primary floodplain of the San Francisco Estuary. The partially leveed floodplain is a major flood control feature for the Sacramento Valley based on its ability to safely convey floodwaters that would otherwise inundate Valley communities. Agricultural lands and seasonal and permanent wetlands within the Bypass represent a key link for waterfowl migrating through the Pacific Flyway. Our studies demonstrate that the floodplain also provides important seasonal habitat for fish. Sampling to date shows that the Bypass supports at least 42 fish species, including both migratory and resident types. The floodplain appears to be especially valuable habitat for two federally-listed fish, Sacramento splittail (Pogonichthys macrolepidotus) and juvenile chinook salmon (Onchorhynchus tshawytscha). The region has considerable potential for additional fish and wildlife benefits as a result of new habitat restoration efforts.

Sommer, T. R., M. L. Nobriga, B. Harrell, W. Batham, and W. J. Kimmerer. (2001). "Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival." Canadian Journal of Fisheries and Aquatic Sciences 58: 325-333.

In this study, we provide evidence that the Yolo Bypass, the primary floodplain of the lower Sacramento River (California, U.S.A.), provides better rearing and migration habitat for juvenile chinook salmon (Oncorhynchus tshawytscha) than adjacent river channels. During 1998 and 1999, salmon increased in size substantially faster in the seasonally inundated agricultural floodplain than in the river, suggesting better growth rates. Similarly, coded-wire-tagged juveniles released in the floodplain were significantly larger at recapture and had higher apparent growth rates than those concurrently released in the river. Improved growth rates in the floodplain were in part a result of significantly higher prey consumption, reflecting greater availability of drift invertebrates. Bioenergetic modeling suggested that feeding success was greater in the floodplain than in the river, despite increased metabolic costs of rearing in the significantly warmer floodplain. Survival indices for coded-wire-tagged groups were somewhat higher for those released in the floodplain than for those released in the river, but the differences were not statistically significant. Growth, survival, feeding success, and prey availability were higher in 1998 than in 1999, a year in which flow was more moderate, indicating that hydrology affects the quality of floodplain rearing habitat. These findings support the predictions of the flood pulse concept and provide new insight into the importance of the floodplain for salmon.

Sommer, T. R., L. Conrad, G. O'Leary, F. Feyrer, and W.C. Harrell (2002). "Spawning and Rearing of Splittail in a Model Floodplain Wetland." Transactions of the American Fisheries Society 131(5): 966-974.

The splittail Pogonichthys macrolepidotus, which has been listed as threatened by the U.S. government, does not produce strong year-classes unless it has access to the floodplain habitat of the San Francisco estuary and its tributaries. In this small-scale, single-year study, we tested the hypothesis that managed inundation of a floodplain can be used to support splittail reproduction in dry years, when this habitat type is not readily available. Adult splittails were captured on their 2001 upstream spawning migration and transferred to a 0.1-ha model floodplain wetland. Our results suggest that adults will successfully spawn if they are provided access to floodplain habitat in dry years. In snorkel surveys, progeny showed a significant association with the lower portion of the water column. Young splittails (15-20 mm fork length [FL]) concentrated in edge habitat near an inflow during the day but at night moved into deeper-water habitats, including open water and habitats with submerged vegetation. Larger splittails (28-34 mm FL) used a broad range of habitats both during the day and at night. Juveniles showed significant schooling behavior during the day, then dispersed at night. These observations have potential implications for the design of habitat restoration projects for the splittail, the last remaining representative of its genus.

Sommer, T. R., W.C. Harrell, M.L. Nobriga, and R. Kurth (2003). Floodplain as habitat for native fish: Lessons from California’s Yolo Bypass. 2001 Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento.

In the following paper we describe the Yolo Bypass, the primary floodplain of the San Francisco
Estuary. The partially leveed floodplain is a major flood control feature for the Sacramento Valley based on
its ability to safely convey floodwaters that would otherwise inundate Valley communities. Agricultural
lands and seasonal and permanent wetlands within the Bypass represent a key link for waterfowl migrating
through the Pacific Flyway. Our studies demonstrate that the floodplain also provides important seasonal
habitat for fish. Sampling to date shows that the Bypass supports at least 42 fish species, including both
migratory and resident types. The floodplain appears to be especially valuable habitat for two federally-listed
fish, Sacramento splittail (Pogonichthys macrolepidotus) and juvenile chinook salmon (Onchorhynchus
tshawytscha). The region has considerable potential for additional fish and wildlife benefits as a result of
new habitat restoration efforts.

Sommer, T. R., W.C. Harrell, R. Kurth, F. Feyrer, S.C. Zeug, and G. O'Leary (2004). Ecological patterns of early life stages of fishes in a large river-floodplain of the San Francisco Estuary. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi. Bethesda, Maryland, American Fisheries Society. Symposium 39: 111-123.

We examined assemblage patterns of early life stages of fishes for two major tributaries of the upper San Francisco Estuary: (1) Sacramento River channel, and (2) Yolo Bypass, the river’s seasonal floodplain. Over four hydrologically diverse years (1999–2002), we collected 15 species in Yolo Bypass egg and larval samples, 18 species in Yolo Bypass rotary screw trap samples, and 10 species in Sacramento River egg and larval samples. Fishes captured included federally listed species (delta smelt Hypomesus transpacificus and splittail Pogonichthys macrolepidotus) and several game species (American shad Alosa sapidissima, striped bass Morone saxatilis, crappie Pomoxis spp., and Chinook salmon Oncorhynchus tshawytscha). As in other regions of the estuary, alien fish comprised a large portion of the individuals collected in Yolo Bypass (40–93% for egg and larval net samples; 84–98% for rotary screw trap samples) and Sacramento River (80–99% for egg and larval net samples). Overall ranks of species abundances were significantly correlated for Yolo Bypass and Sacramento River, suggesting that each assemblage was controlled by similar major environmental factors. However, species diversity and richness were higher in Yolo Bypass, likely because of a wider variety of habitat types and greater hydrologic variation in the floodplain. In both landscapes, we found evidence that timing of occurrence of native fishes was earlier than aliens, consistent with their life history and our data on adult migration patterns. We hypothesize that Yolo Bypass favors native fishes because the inundation of seasonal floodplain typically occurs early in the calendar year, providing access to vast areas of spawning and rearing habitat with an enhanced food web. Conclusions from

this analysis have implications for the management of aquatic biodiversity of tributaries to the San Francisco Estuary and perhaps to other lowland rivers.

Sommer, T. R., W.C. Harrell, A. Mueller-Solger, B. Tom, and W.J. Kimmerer (2004). "Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA." Aquatic Conservation: Marine and Freshwater Ecosystems 14(3): 247-261.
(1)Despite progress in the development of conceptual models of river processes, the validation and application of these models to conservation may be limited by a deficit of tools for intermediate-scale (1–100km) reaches. A model was developed to examine the effect of variation in flow on the responses of two trophic levels in a large temperate river (Sacramento River) and its seasonal floodplain (Yolo Bypass). Field data and hydrologic simulations were evaluated for three hydrologically diverse years. (2)The simulations showed much more hydrologic variability in the floodplain than the river, with greater total surface and shallow area, longer hydraulic residence times, and lower water velocities for the floodplain. (3)Chlorophyll a levels were significantly higher in the floodplain than in the river, and were negatively associated with flow. These results were consistent with longer hydraulic residence times, increased surface area of shallow water, and warmer water temperatures. (4)Copepods and cladoceran densities were similar in the river and its floodplain, and were mostly negatively associated with flow. (5)There were significantly higher densities of Diptera and terrestrial invertebrates in the floodplain than the river. Diptera densities in the floodplain were positively associated with flow. (6)These results provide evidence of the incremental value of floodplain habitat to the conservation of large rivers. In particular, it appears that providing river–floodplain connectivity can enhance production of lower trophic levels at relatively rapid time scales, probably benefitting secondary consumers, including Chinook salmon (Onchyrhynchus tshawytscha).

Sommer, T. R., W. Harrell, and M.L. Nobriga (2005). "Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain." North American Journal of Fisheries Management 25(4): 1493-1504.
Although juvenile Chinook salmon Oncorhynchus tshawytscha are known to use a variety of habitats, their use of seasonal floodplains, a highly variable and potentially risky habitat, has not been studied extensively. Particularly unclear is whether a seasonal floodplain is a net "source" or a net "sink" for salmonid production. To help address this issue, we studied salmon habitat use in the Yolo Bypass, a 24,000-ha floodplain of the Sacramento River, California. Juvenile salmon were present in the Yolo Bypass during winter-spring; fish were collected in all regions and substrates of the floodplain in diverse habitats. Experimental releases of tagged hatchery salmon suggest that the fish reared on the floodplain for extended periods (mean = 33 d in 1998, 56 d in 1999, and 30 d in 2000). Floodplain rearing and associated growth are also supported by the significantly larger size of wild salmon at the floodplain outlet than at the inlet during each of the study years. Several lines of evidence suggest that although the majority of young salmon successfully emigrated from the floodplain, areas with engineered water control structures had comparatively high rates of stranding. Adult ocean recoveries of tagged hatchery fish indicate that seasonal floodplains support survival at least comparable with that of adjacent perennial river channels. These results indicate that floodplains appear to be a viable rearing habitat for Chinook salmon, making floodplain restoration an important tool for enhancing salmon production.

Sommer, T. R., G.M. Benigno, and P.S. Cranston (2006). New invertebrate species found in Yolo Bypass. IEP Newsletter. 19: 4.

Sommer, T. R., G.M. Benigno, and P.S. Cranston (2006). "New species discovered in Yolo Bypass." Yolo Flyway, A Publication of the Yolo Basin Foundation 15(2): 1-2.

Sommer, T. R., R. Baxter, and F. Feyrer (2007). Splittail “delisting”: A review of recent population trends and restoration activities Status, distribution, and conservation of native freshwater fishes of western North America M. J. Brouder, and J. A. Scheurer. Bethesda, Maryland, American Fisheries Society Symposium 53: 25-38.

Splittail Pogonichthys macrolepidotus, a minnow native to the San Francisco Estuary, was originally listed by the U.S. Fish and Wildlife Service as threatened in 1999. The listing was remanded in 2003 based on recent evidence about its status and efforts to restore the species. Although young-of-year production declined during a 6-year drought prior to the listing, the return of wet conditions in the late 1990s resulted in record indices of abundance. Much of the minnow's historical off-channel habitat was lost by the early 1900s, but surveys suggest that the current range of splittail has stabilized. Year-class strength is directly related to the duration of inundation of remaining floodplain. Adults migrate upstream in winter or early spring to spawn on seasonally inundated vegetation. Their offspring rear in the food-rich floodplain habitat before emigrating with receding floodwaters. Based on the recognition that the species is perhaps one of the most floodplain-dependent fishes in the estuary, floodplain restoration became a central component of a major agency/stakeholder effort to fix long-standing problems in the region. Floodplain restoration is likely to substantially improve the long-term status of splittail, although extreme alterations in the food web from alien species may prevent the minnow from returning to historical levels.

Sommer, T. R., W.C. Harrell, and T. R. Swift (2008). "Extreme hydrologic banding in a large-river Floodplain, California, U.S.A." Hydrobiologia 598: 409-415.
Where tributaries meet, certain conditions of flow and topography often result in incomplete mixing and the formation of spatially and temporally persistent plumes or bands. Yolo Bypass, the primary floodplain of the lower Sacramento River (California, USA), provides an extreme example of this effect. Inspection of recent and historical aerial photographs revealed that the four major tributaries of Yolo Bypass typically do not substantially mix laterally within the floodplain. The phenomenon is notable in the number of tributaries involved (4), the distance over which the bands remain distinct (>61 km), and the persistence of the bands despite channel constrictions and long cross-wind fetch. This effect demonstrates the importance of lateral variability during floodplain flow events, including transport and distribution of chemical constituents, and habitat for fish and other organisms that use floodplains as migration corridors and rearing areas.

Sommer, T. R., W.C. Harrell, Z. Matica, and F. Feyrer (2008). "Habitat Associations and Behavior of Adult and Juvenile Splittail (Cyprinidae: Pogonichthys macrolepidotus) in a Managed Seasonal Floodplain Wetland " San Francisco Estuary and Watershed Science 6(2): Article 3.
Although there is substantial information about the benefits of managed seasonal wetlands to wildlife, little is known about whether this habitat can help support “at risk” native fishes. The Sacramento splittail Pogonichthys macrolepidotus, a California Species of Special Concern, does not produce strong year classes unless it has access to floodplain wetlands of the San Francisco Estuary and its tributaries. Our study examined the potential use of managed inundation to support spawning and rearing of splittail in years when the availability of seasonal habitat is limited. Wild adult splittail were captured during their spawning migration and transferred to a 3.8-ha engineered wetland, where they successfully spawned shortly after introduction. Radio telemetry studies suggested that post-spawning adults were relatively sedentary over the study period. Adult splittail were primarily located in habitats with open water or light vegetation, and in the deepest portions of the wetland. Snorkel surveys showed that early stages (mean 21-mm fork length [FL]) of young splittail produced in the wetland were strongly associated with shallow areas with shoreline emergent terrestrial vegetation and submerged aquatic vegetation, but moved offshore to deeper areas with tules and submerged terrestrial vegetation at night. Larger juveniles (mean 41-mm FL) primarily used deeper, offshore habitats during day and night. At night, schools of both younger and older juveniles dispersed, and individuals were associated with the bottom of the water column. These observations have important implications for the construction of managed and restored wetlands for the benefit of native fishes.

Sommer, T. R., C.K. Reece, and F. Mejia (2009). Delta smelt life-history contingents: A possible upstream rearing strategy? . IEP Newsletter 22: 11-13.

Sommer, T. R., F. Mejia, M. Nobriga, F. Feyrer, and L. F. Grimaldo (2010). The spawning migration of delta smelt in the upper San Francisco Estuary. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Sommer, T. R., C. Armor, et al. (2007). "The Collapse of Pelagic Fishes in the Upper San Francisco Estuary: El Colapso de los Peces Pelagicos en La Cabecera Del Estuario San Francisco." Fisheries 32(6): 270-277.
Although the pelagic fish community of the upper San Francisco Estuary historically has shown substantial variability, a recent collapse has captured the attention of resource managers, scientists, legislators, and the general public. The ecological and management consequences of the decline are most serious for delta smelt (Hypomesus transpacificus), a threatened species whose narrow range overlaps with large water diversions that supply water to over 25 million people. The decline occurred despite recent moderate hydrology, which typically results in at least modest recruitment, and investments of hundreds of millions of dollars in habitat restoration and environmental water allocations to support native fishes. In response to the pelagic fish collapse, an ambitious multi-agency research team has been working since 2005 to evaluate the causes of the decline, which likely include a combination of factors: stock-recruitment effects, a decline in habitat quality, increased mortality rates, and reduced food availability due to invasive species.

Souza, K. (2010). 2010 IEP program activities update. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Sowers, J., R. Dulberg, C. Richard, R. Givler, A. Tillery, and S. Pearce (2010). Quantitative parameters of change: Contrasting historical fluvial systems and urban drainage systems in the San Francisco Bay Area. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Urbanization of the San Francisco Bay area has brought significant changes in the nature of local streams and their watersheds. A compilation of data from 1:24,000-scale mapping of the bay area prepared for the Oakland Museum of California’s series, Creek & Watershed Maps of the San Francisco Bay Area, allows quantification of the degree of alteration of these streams. Map elements include historical creeks (circa 1850), modern creeks, engineered channels, and underground storm drains (> 24” diameter). Creeks and channels mapped have a minimum watershed size of 0.2 km2. Former tidal marsh areas are excluded. Using ArcGIS, the lengths of each of these watercourse types can be summed for any given area, and simple parameters computed depending on the interests of the user. Watershed name Laurel Creek/Colma Creek, Size (sq. km) 10/38, Historical creeks (km) 11/48, Modern creeks (km) 6/4, Engineered channels (km) 1/8, Underground storm drains (km) 14/73, Creek length loss 45%/92%, Creek length loss 45%/92%, Drainage density change 1.9X/1.8X. Initial analysis shows the two most significant changes to be the net loss of natural creeks as they are replaced by engineered channels and underground storm drains or flooded by reservoirs, and the increase in drainage density through the addition of engineered channels and underground storm drains in areas without natural creeks. Example data above show net creek losses of 45% and 92% and drainage density increases of 1.9 times and 1.8 times for Laurel Creek in San Mateo and Colma Creek in Daly City, respectively. These changes have profound implications for runoff quantities, flood peak height and timing, erosion and sedimentation, and riparian habitat availability. The published map series and GIS coverage are available for much of the San Francisco Bay area at www.museumca.org/creeks.

Speed, T. (1993). Modeling and managing a salmon population. Statistics for the environment. V. Barnett, and F. Turkman. New York, NY, John Wiley & Sons, Ltd.: 271-291.

Speekmann, C. L., S. M. Bollens, et al. (2000). "The effect of ultraviolet radiation on the vertical distribution and mortality of estuarine zooplankton." Journal of Plankton Research 22(12): 2325-2350.
The effect of UV-B radiation on the vertical distribution of three calanoid

copepod species (Tortanus dextrilobatus, Acartiura spp. and Acanthacartia spp.) and three larval stages of Pacific herring, Clupea pallasi (1-, 7-, and 14-day-old larvae) was investigated. A series of 2 m high columnar tanks equipped with infra-red light and video-microscopy was used to investigate the vertical distribution of zooplankton in the presence and absence of UV-B radiation. In the presence of UV-B radiation, T.dextrilobatus and 1-day-old C.pallasi resided about 50 cm deeper than in the absence of UV-B, while Acartiura spp. and Acanthacartia spp. showed no (or only minimal) change in vertical distribution. Mortality experiments were also conducted outdoors in which each copepod species was exposed to full or reduced natural radiation levels. Only T.dextrilobatus showed an increase in mortality when exposed to full radiation. Our results showed that T.dextrilobatus and 1-day-old C.pallasi larvae were sensitive to UV radiation (UVR), and to reduce or eliminate UV-induced stress, they avoided the surface of the water column when UV-B radiation was present. Copepod species were chosen to span a range of pigmentation: T.dextrilobatus (heavily pigmented), Acartiura spp. (moderately pigmented) and Acanthacartia spp. (not pigmented). The pigmentation did not appear to play a role in UVR tolerance of the copepods, but may be a factor determining UV tolerance of C.pallasi.

Spencer, D. F. and G. G. Ksander (2005). "Seasonal Growth of Water hyacinth in the Sacramento/San Joaquin Delta, California." Journal of Aquatic Plant Management 43(2): 91-94.

Waterhyacinth (Eichhornia crassipes (Mart.) Solms), is a serious problem in the Sacramento / San Joaquin Delta, California. There is little published information on its phenology or seasonal growth in this system. Waterhyacinths were sampled at 2 to 3 week intervals from November, 1995 to July, 1997 and the following measurements were made on individual plants: dry weight, height, number of living leaves, number of dead leaves, and the width of the largest lamina. Lamina area per plant was estimated by multiplying the number of living leaves by the mean lamina area for each sampling date. We also noted the presence or absence of flowers. Height and dry weight increased from less than 10 cm in winter and early spring to more than 80 cm in late summer and from 10 g to 85 g, respectively. Number of dead leaves was greatest in the winter and declined through June. New leaves started to appear in March. Starting in March, lamina area per plant increased through October. Plants with flowers were present at the sample site from May 20 to August 12 but not abundant. A logistic regression equation relating relative lamina area per plant to accumulated degree-days was developed. Maximum growth was achieved in October, later than previously reported for waterhyacinth in southeast U.S. populations.

Spencer, D. F., G. G. Ksander, et al. (2006). "Evaluation of Waterhyacinth Survival and Growth in the Sacramento Delta, California, Following Cutting." Journal of Aquatic Plant Management 44(1): 50-60.

Waterhyacinth (Eichhornia crassipes (Mart.) Solms), is a serious problem in the Sacramento Delta, currently managed with herbicides and to a lesser extent biological control insects. The search for alternative methods continues. The purpose of this study was to test the hypothesis that waterhyacinth would not survive treatments made by three types of cutting machines mounted on boats and thus result in open water areas. Waterhyacinth mats were treated by machines 1 and 2 during September, 2003 at Lambert Slough, south of Sacramento, California and at the Dow Wetlands, near Antioch, California. In June 2004, machine 3 cut plants in the Dow Wetlands. Machine 1 sheared off the leaves resulting in many plant fragments and plants that consisted of floating stem bases with intact root systems. The cutting motions of machines 2 and 3 differed and these machines produced numerous plant fragments along with ramets that had been split along a vertical axis into nearly intact ramets with broken leaves. Plants collected immediately after the treatments and grown either in situ or in tubs in Davis, California began to produce new leaves within one week of treatment. Leaf production rates were higher for cut than for un-cut plants. Similarly, plant dry weight increased over the course of the experiments. All of the plants survived in the tub experiments and 65% of them survived in field enclosures for at least six weeks. At Lambert Slough, >50% of the surface was covered by floating plant debris (2446 g dry weight m super(-2) and 1589 g dry weight m super(-2)) after four and six weeks even though the expectation was that the material would sink and decompose within three weeks. Cutting Waterhyacinth with the three machines evaluated in this study did not immediately (i.e., within six months) produce weed free areas of open water in habitats typical of those found in the Sacramento/San Joaquin Delta.

Spies, R. B., D.W. Rice and J. Felton. (1988). "Effects of organic contaminants on reproduction of starry flounder, Platichthys stellatus (Pallas) in San Francisco Bay. Part I: Hepatic contamination and mixed-function oxidase (MFO) activity during the reproductive season." Marine Biology 98(2): 181-189.

Concentrations of neutral organic contaminants and activities of microsomal P-450 mixed-function oxidase (MFO) were measured in the livers of the starry flounder Platichthys stellatus (Pallas), collected from more- and less-contaminated sites in San Francisco Bay, during the 1984–1985 reproductive season. Starry flounder collected at the Berkeley (Bk) site, located in the more urbanized central portion of San Francisco Bay, had greater liver concentrations of polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAH) (fluorescence equivalents of pyrene) than those collected at a site in northern San Pablo Bay (SP), where urban development is less intense and more distant. Hepatic aryl hydrocarbon hydroxylase (AHH) activity, a particular MFO, in males and in gonadally immature females fluctuated significantly from September 1984 through April 1985 with the Bk population exhibiting significantly greater activities during this period. Site differences were especially notable during the time of spawning (January–March), as AHH activities of starry flounder from SP declined and those from Bk remained elevated. These site differences appear to be due to P-450 isozymes (e.g. P-450E) whose activities are inducible by some PCBs and PAHs, as males and gonadally immature females from the two sites were not different in their hepatic AHH activities when assayed in the presence of an inhibitor of P-450E, 7,8-benzoflavone (7,8-BF). Greatly reduced hepatic AHH activities in females coincided with the onset of vitellogenesis; however, a comparison of female starry flounder bearing yolky eggs from the two sites during several successive reproductive seasons indicated significantly greater AHH activity in those caught at Bk than those from SP. There was a linear relationship between hepatic AHH activity and its inhibition by 7,8-BF in all P. stellatus assayed and more than 98% of individuals caught in San Francisco Bay had hepatic AHH activites that were suppressed by 7,8-BF. Therefore, widespread induction of hepatic microsomal P-450 by PAH-type compounds in San Francisco Bay is indicated and, further, P-450 induction is apparent in female starry flounder in a portion of San Francisco Bay during gametogenesis and the time of spawning.

Spies, R. B., and D.W. Rice. (1988). "Effects of organic contaminants on reproduction of starry flounder, Platichthys stellatus (Pallas) in San Francisco Bay. Part II:Reproductive success of fish captured in San Francisco Bay and spawned in the laboratory." Marine Biology 98(2): 191-200.

Gonadally mature Platichthys stellatus (Pallas) were captured at two localities in San Francisco Bay in 1983–1985 and were induced to spawn in the laboratory; they were evaluated for relationships between several measures of survival through successive early life-history stages, chlorinated hydrocarbon concentrations in maternal liver and spawned eggs, and maternal hepatic mixed-function oxidase (MFO) activity. The effect of laboratory holding on hepatic aryl hydrocarbon hydroxylase (AHH), a particular MFO activity, and concentrations of chlorinated hydrocarbons were also evaluated. Significant negative correlations were found between maternal hepatic AHH activity at the time of spawning and percent viable (floating) eggs, fertilization success, and embryological success. Embryological success was also negatively correlated with concentrations of polychlorinated biphenyls (PCBs) in eggs. Laboratory holding for 45d, about twice the mean time to spawning, resulted in no significant changes in chlorinated hydrocarbon concentrations, but significant decreases in liver concentrations of phthalate esters and hepatic AHH activity. Females captured at the more urbanized central bay site, Berkeley (Bk), had a lesser proportion of floating eggs, poorer fertilization success, and higher hepatic AHH activities than those captured at a site in northern San Pablo Bay (SP). These results indicate the potential for a serious effect of lipophilic neutral organic contaminants on reproduction of an important estuarine flatfish species. Several mechanisms of toxic action are suggested to account for the observed effects, including the binding of toxic

metabolites of contaminants to macromolecules and the alteration of sex steroids in females with contaminant-induced P-450 isozyme(s).

Spies, R. B., B. D. Andresen, et al. (1987). "Benzthiazoles in estuarine sediments as indicators of street runoff." Nature 327: 697-699.
Street runoff can be a major source of potentially toxic aromatic compounds that enter estuaries, embayments and ocean inlets. While investigating contaminated sediments in San Francisco Bay the authors discovered several benzthiazoles, which appear to be derived from the use of anti-oxidants in the manufacture of rubber tyres. Their investigations confirm that two of these compounds, benzthiazole and 2-(4-morpholinyl)-benzthiazole, occur in street runoff and that they can result from the weathering of a commercially used anti-oxidant in rubber manufacture. These compounds are proposed as potential indicators of the contribution of street runoff to the contaminants in sediments of urban coastal areas.

Spies, R. B. and D. W. J. Rice (1988). "Effects of organic contaminants on reproduction of the starry flounder Platichthys stellatus in San Francisco Bay. I. Reproductive success of fish captured in San Francisco Bay and spawned in the laboratory." Marine Biology 98: 191-200.
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Spies, R. B., D. W. J. Rice, et al. (1988). "Effects of organic contaminants on reproduction of the starry flounder Platichthys stellatus in San Francisco Bay. I. Hepatic contamination and mixed-function oxidase (MFO) activity during the reproductive season." Marine Biology 98: 181-189.
Concentrations of neutral organic contaminants and activities of microsomal P-450 mixed-function oxidase (MFO) were measured in the livers of the starry flounder Platichthys stellatus , collected from more- and less-contaminated sites in San Francisco Bay. Starry flounder collected at the Berkeley (Bk) site, located in the more urbanized central portion of San Francisco Bay, had greater liver concentrations of polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAH) (fluorescence equivalents of pyrene) than those collected at a site in northern San Pablo Bay (SP), where urban development is less intense and more distant. Hepatic aryl hydrocarbon hydroxylase (AHH) activity, a particular MFO, in males and in gonadally immature females fluctuated significantly from September 1984 through April 1985.

Spiker, E. C. and L. E. Schemel (1979). Distribution and stable-isotope composition of carbon in San Francisco Bay. San Francisco Bay: the Urbanized Estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 195-212.

Spragens, K., K. Thorne, and J.Y. Takekawa (2010). Exceptional tides, devastating effects: tidal marsh dynamics and species’ habitats. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Sea-level rise poses direct long-term threats to tidal marsh persistence and species habitat availability. However, the occurrence and synergistic effects of extreme events may prove to have more devastating consequences in the near future. The San Francisco Bay estuary provides important habitat for federally and state listed species, including the salt marsh harvest mouse (Reithrodontomys raviventris), California clapper rail (Rallus longirostris obsoletus), and California black rail (Laterallus jamaicensis coturniculus). Increases in maximum tide heights, storm frequency and intensity may create bottleneck events in the form

of increased predation and increased nest failure. We have deployed several water loggers at 11 sites throughout the San Francisco Bay estuary. Using elevation and vegetation models derived from high resolution RTK-GPS surveys and species habitat use data we discuss site-specific inundation patterns, extreme tide events, and potential consequences to tidal marsh habitats and the species reliant upon them.

Spratt, J. D. (1981). "Status of the Pacific herring,Clupea harengus pallasi, in California to 1980." California Department of Fish and Game, Fish Bulletin 171: 1-104.

The California Department of Fish and Game has conducted periodic studies on Pacific herring since 1953. This report concentrates on the period from 1972 through 1980 during which the herring fishery underwent a dramatic resurgence due to the opening of a lucrative market for herring roe in Japan. The spawning biomass of Pacific herring was estimated by determining numbers of eggs spawned and using previously derived estimates of eggs per gram of fish to convert this figure to short tons of herring. Sampling th roe fishery catch in Tomales and San Francisco Bays revealed that age 2 and 3 herring dominated the round haul fishery, and ages 5 and 6 dominated the gill net fishery. Gill nets consistently caught larger herring and a higher percentage of females than round haul nets. Comparison of length at age of herring from Tomales and San Francisco Bays revealed a statistical difference in growth rates between populations of the two bays. Spawning time was related to the tidal cycle in San Francisco Bay. From 1973 through 1976, 88% of all spawnings occurred when the daily high tide was at night.

Spratt, J. D. (1992). "The evolution of California's herring roe fishery: catch allocation, limited entry, and conflict resolution." California Fish and Game 78: 20-44.

California's Pacific herring (Clupea pallasi) roe fishery began in 1973. A formal limited entry program was adopted in 1977 and the number of herring permits issued for the major fishing areas of San Francisco and Tomales Bays peaked at 471 permits in the 1982-83 season. In 1989, the Legislature adopted a policy to allow the sale of permits. The majority of herring permits are issued for San Francisco Bay. San Francisco Bay herring quotas are allocated approximately 33% to round haul (purse seine and lampara nets) vessels and 67% to gill net vessels. San Francisco Bay is surrounded by a metropolitan area, and many fishing areas have been closed due to conflicts with recreational users and noise pollution near private residences. In conjunction with the test boat system, an important pre-spawn staging area of San Francisco Bay was closed to gill net fishing in 1991. Congestion and socioeconomic issues were less of a problem in Tomales Bay due to the fewer number of permits and the rural nature of the surrounding communities.

Squire, S., G. M. Scelfo, et al. (2002). "Decadal trends of silver and lead contamination in San Francisco Bay surface waters." Environmental Science and Technology 36: 2379-2386.

Over the past decade, San Francisco Bay surface waters have remained enriched with dissolved (<0.45 mum) silver and lead concentrations (decadal means of 5.7 ng kg(-10) Ag-[filtered] and 31 ng kg(-1) Pb-[filtered] compared with those (0.26 ng kg(-1) Ag-[filtered] and 2.7 ng kg(-1) Pb-[filteredl]) Of adjacent oceanic surface waters of the northeast Pacific, despite efforts to reduce pollutant loadings to the Bay during that period. While time series models show that there has been a 40% decline in total lead concentrations in the southern reach of the estuarine system between 1989 and 1999, the filtered lead fraction has not changed significantly during that time. That persistence is attributed to (i) the ongoing input from previous atmospheric depositions and industrial lead to its drainage basin, which are slowly being advected into the estuary and (ii) the internal recycling of lead between the surface sediments and the water column within the Bay. In contrast, both filtered and total silver concentrations in the southern reach have declined by 70% and 40%, respectively, within the past decade. These temporal declines are attributed to a 2-fold decrease in silver loadings from publicly owned treatment works and a comparable decline in the silver concentration of surficial sediments within that region during the past decade. In the northern reach, silver and lead concentrations have remained essentially constant between 1989 and 1999, reflecting invariable anthropogenic input of these elements to this embayment over that decade.

Stacey, M. T., S.G. Monismith, and J.R. Burau (1999). "Observations of turbulence in a partially stratified estuary." Journal of Physical Oceanography 29: 1950-1970.
The authors present a field study of estuarine turbulence in which profiles of Reynolds stresses were directly measured using an ADCP throughout a 25-h tidal day. The dataset that is discussed quantifies turbulent mixing for a water column in northern San Francisco Bay that experiences a sequence of states that includes a weak ebb and flood that are stratified, followed by a strong, and eventually unstratified, ebb and flood. These measurements show that energetic turbulence is confined to a bottom mixed layer by the overlying stratification. Examination of individual Reynolds stress profiles along with profiles of Richardson number and turbulent Froude number shows that the water column can be divided into regions based on the relative importance of buoyancy effects. Using the measured turbulence production rate P, the dissipation rate e is estimated. The observed turbulence had values of e/vN2 > 20 all of the time and e/vN2 > 200 most of the time, suggesting that the observed motions were buoyancy affected turbulence rather than internal waves. However, at times, turbulent Froude numbers in much of the upper-water column were less than one, indicating important stratification effects. Taken as a whole, the data show that stratification affects the turbulent velocity variance q2 most severely; that is, observed reductions in u'w' are largely associated with small values of q2 rather than with a dramatic reduction in the efficiency with which turbulent motions produce momentum fluxes. Finally, the dataset is compared to predictions made using the popular Mellor-Yamada level 2.5 closure. These comparisons show that the model tends to underestimate the turbulent kinetic energy in regions of strong stratification where the turbulence is strongly inhomogeneous and to overestimate the turbulent kinetic energy in weakly stratified regions. The length scale does not appear to compensate for these errors, and, as a result, similar errors are seen in the eddy viscosity predictions. It is hypothesized that the underestimation of q2 is due to an inaccurate parameterization of turbulence self-transport from the near-bed region to the overlying stratification.

Stacey, M. T., J. R. Burau, et al. (2001). "Creation of residual flows in a partially stratified estuary." Journal of Geophysical Research. C. Oceans 106(C8): 13-17.
The creation of residual flows in estuaries is examined using acoustic Doppler current profiler data sets from northern San Francisco Bay. The data sets are analyzed using principal component analysis to examine the temporal variability of the flows which create the residual circulation. It is seen that in this periodically and partially stratified estuary the residual flows are created through a series of pulses with strong variability at the 24-hour timescale, through the interaction of shear, stratification and mixing. This interaction is captured through the use of a dimensionless number, the horizontal Richardson number (Ri sub(x)), which is developed to examine the local balance between the stratifying and destratifying forces at the tidal timescale. It is seen that Ri sub(x) is a valuable parameter in predicting the onset of the residual-creating events, with a threshold value of approximately 3 on ebb tides. This critical value is argued to be a threshold, above which the stratification and shear flow create a feedback effect, each further intensifying the other. This feedback results in a highly variable exchange flow which creates the estuarine residual in intermittent pulses rather than as a steady flow. Although typically attributed to baroclinic forcing, an argument is made that these pulses of residual-creating exchange flow could be created by barotropic forcing in the presence of variable stratification which is asymmetric between flood and ebb tides. This result poses a great challenge for turbulence modeling, as the timing and magnitude of stratification and shear must be correctly simulated on the tidal timescale in order to reproduce the effects seen in the data sets presented.

Stacey, M. T., S. G. Monismith, et al. (1999). "Measurement of Reynolds stress profiles in unstratified tidal flow." Journal of Geophysical Research 104: 10933-10949.
In this paper we present a method for measuring profiles of turbulence quantities using a broadband acoustic doppler current profiler (ADCP). The method

follows previous work on the continental shelf and extends the analysis to develop estimates of the errors associated with the estimation methods. ADCP data was collected in an unstratified channel and the results of the analysis are compared to theory. This comparison shows that the method provides an estimate of the Reynolds stresses, which is unbiased by Doppler noise, and an estimate of the turbulent kinetic energy (TKE) which is biased by an amount proportional to the Doppler noise. The noise in each of these quantities as well as the bias in the TKE match well with the theoretical values produced by the error analysis. The quantification of profiles of Reynolds stresses simultaneous with the measurement of mean velocity profiles allows for extensive analysis of the turbulence of the flow. In this paper, we examine the relation between the turbulence and the mean flow through the calculation of u sub(*), the friction velocity, and C sub(d), the coefficient of drag. Finally, we calculate quantities of particular interest in turbulence modeling and analysis, the characteristic lengthscales, including a lengthscale which represents the stream-wise scale of the eddies which dominate the Reynolds stresses.

Stanley, S. E., P.B. Moyle, and H.B. Shaffer. (1995). "Allozyme analysis of delta smelt, Hypomesus transpacificus and longfin smelt, Spirinchus thaleichthys in the Sacramento-San Joaquin Estuary, California." Copeia 2: 390-396.

Two species of smelt (Osmeridae), Hypomesus transpacificus and Spirinchus thaleichthys, found in the Sacramento-San Joaquin estuary recently have declined in abundance, and H. transpacificus has been threatened by the introduction of nonnative Hypomesus nipponensis. We conducted an allozyme analysis of five species of smelt found in California to determine whether the threatened populations are distinct genetically and to evaluate the possibility of introgression of foreign alleles in H. transpacificus. Native H. transpacificus and introduced H. nipponensis differed genetically (Nei's D = 0.883) and were allelically distinct at 13 of 22 loci. Hypomesus transpacificus is more similar genetically to the native marine species, Hypomesus pretiosus (Nei's D = 0.400) than to H. nipponensis, strongly supporting the interpretation that H. transpacificus and H. nipponensis are distinct species. Populations of S. thaleichthys from Washington and the Sacramento-San Joaquin delta are similar genetically (Nei's D = 0.005). However, gene frequencies among these two populations of S. thaleichthys differed significantly, suggesting that current gene flow between them is restricted. This result, combined with geographic isolation suggests that the delta population of S. thaleichthys warrants management as an isolated and genetically distinct entity.

Steding, D. J., C.E. Dunlap, and A.R. Flegal (2000). "New isotopic evidence for chronic lead contamination in the San Francisco Bay estuary system: Implications for the persistence of past industrial lead emissions in the biosphere." Proceedings of the National Academy of Sciences of the United States of America 97(21): 11181-11186.

Measurements of lead isotope compositions in unfiltered San Francisco Bay waters from 1989 to 1998 have brought new insights into the cycling of anthropogenic lead in estuaries. Isotopic compositions of lead in the shallow (<2 m) southern reach were essentially invariant (~90% derived from 1960s–1970s leaded gasoline) during the study period because of limited hydraulic flushing and the remobilization of lead from bottom sediments. In contrast, in the northern reach freshwater flushing from the San Joaquin and Sacramento rivers produced seasonal and decadal variations in lead isotope compositions. The seasonal shifts are attributed to advection of soils containing late 1980s gasoline lead into the bay during winter rains. Mass balance calculations indicate that only a small fraction (1–10%) of this leaded gasoline fallout from the late 1980s has been washed out of the San Joaquin and Sacramento rivers' drainage basin by 1995. Superimposed on this seasonal cycling was a long-term systematic shift in the component of gasoline lead expressed in the river systems, with a small (~5–10%) decrease in the amount of 1960s–1970s gasoline lead in river and North Bay waters. The retention of gasoline lead in the river systems draining into the bay as well as San Francisco Bay sediments indicates that historic gasoline deposits may remain in the combined riparian/estuarine system for decades. Such a persistence is in contraindication to recent reports of rapid (annual) decreases in lead contamination in other environments, and the link between climate and contaminant transport suggests local or global climate change will have an impact on contaminant distribution and fate.

Steding, D. J., C. E. Dunlap, et al. (2000). "New isotopic evidence for chronic lead contamination in the San Francisco Bay estuary system: Implications for the persistence of past industrial lead emissions in the biosphere." Proceedings of the National Academy of Sciences, USA 97(21): 11181-11186.
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Steel, A., and A.P. Klimley (2010). Fine-scale movement of largemouth bass (Micropterus salmoides) and potential for open-water predation. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Steel, A., and P. Klimley (2010). Fine-scale movement of largemouth bass, an introduced predator. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The largemouth bass (Micropterus salmoides) is an introduced, generalist predator in the Sacramento-San Joaquin Delta. The top-down pressure exerted by this and other non-native predators has been suggested as one of the potential factors in the decline of a group of pelagic fishes (POD species: delta smelt, longfin smelt, threadfin shad, stripped bass). While largemouth bass are associated with shallow-water habitats, it is not known to what extent they also use open-water zones, and thus what degree of predation pressure they could potentially exert on pelagic species in these areas. Here we use acoustic telemetry techniques to assess fine-scale bass movement over the course of a year. As of June 2010, we have fifteen adult bass implanted with acoustic telemetry tags, and have recorded their fine-scale movements with a Vemco Positioning System in a flooded agricultural island in the south-central Delta. Additionally, we are measuring the extent, density, and composition of the submerged aquatic vegetation within the shallow-water zone. Movements will be analyzed for proximity to submerged aquatic vegetation, conspecific avoidance, core-use areas, and daily/seasonal patterns in these behaviors. Preliminary results from August and September 2009 suggest that while bass do appear to make rare forays into open-water areas (>75m from vegetation beds), the majority of time is spent within or at the edges of the submerged aquatic vegetation. More complete knowledge of the movements and habitat use of M. salmoides in the Delta, when combined with information on the distribution and habitat use of declining pelagic species, will allow us to better assess the role that predation pressure plays in the Delta ecosystem. We hope that this understanding will aid managers in future efforts to aid declining populations and rehabilitate critical habitats.

Stenzel, L. E., H. R. Carter, et al. (1995). "Breeding success of double-crested cormorants in the San Francisco Bay area, California." Colonial Waterbirds 18: 216-224.

Colony size and nesting success of the Double-crested Cormorant (Phalacrocorax auritus) was examined during 1988-90 on the Richmond-San Rafael Bridge (= Bridge) in the San Francisco Bay estuary and at a reference colony on the Farallon Islands, for evidence that pollutants could be harming cormorant reproduction in the estuary. The Bridge colony increased by 43% from 296 to 424 nests by 1990, while the Farallon Island colony (= Island) remained relatively stable at about 290 nests over the three years. Nesting was earlier on the Island than on the Bridge in all year, but on the Bridge there was a trend toward earlier nesting from 1988 to 1990. Success was higher on the Island in 1988, but on the Bridge in 1989 and 1990. The overall mean number of chicks (plus or minus SE) fledged per nest was: 0.98 plus or minus 0.07, 1.78 plus or minus 0.06 and 1.70 plus or minus 0.06 on the Bridge venus 1.29 plus or minus 0.07, 1.13 plus or minus 0.05 and 0.61 plus or minus 0.05 on the Island from 1988-90, respectively. During 9 of 11 time-periods examined, Bridge nesters had higher success than did Island nesters. Poor success on the Bridge in 1988 matched a later timing of nest initiations. Breeding success decreased seasonally at both locations. Breeding success at both colonies was comparable to that reported for other colonies. There were no evidence that reproductive success or colony size was depressed by pollutants at the San Francisco Bay colony.

Stepanauskas, R., M. A. Moran, et al. (2005). "Sources, bioavailability, and photoreactivity of dissolved organic carbon in the Sacramento-San Joaquin River Delta." Biogeochemistry 74(2): 131-149.
We analyzed bioavailability, photoreactivity, fluorescence, and isotopic composition of dissolved organic carbon (DOC) collected at 13 stations in the Sacramento-San Joaquin River Delta during various seasons to estimate the persistence of DOC from diverse shallow water habitat sources. Prospective large-scale wetland restorations in the Delta may change the amount of DOC available to the food web as well as change the quality of Delta water exported for municipal use. Our study indicates that DOC contributed by Delta sources is relatively refractory and likely mostly the dissolved remnants of vascular plant material from degrading soils and tidal marshes rather than phytoplankton production. Therefore, the prospective conversion of agricultural land into submerged, phytoplankton-dominated habitats may reduce the undesired export of DOC from the Delta to municipal users. A median of 10% of Delta DOC was rapidly utilizable by bacterioplankton. A moderate dose of simulated solar radiation (286 W m(-2) for 4 h) decreased the DOC bioavailability by an average of 40%, with a larger relative decrease in samples with higher initial DOC bioavailability. Potentially, a DOC-based microbial food web could support <= 0.6 x 10(9) g C of protist production in the Delta annually, compared to approximate to 17 x 10(9) g C phytoplankton primary production. Thus, DOC utilization via the microbial food web is unlikely to play an important role in the nutrition of Delta zooplankton and fish, and the possible decrease in DOC concentration due to wetland restoration is unlikely to have a direct effect on Delta fish productivity.

Stephenson, M., A. Bonnema, A. Byington, W. Heim, G. Gill, C. Foe, K. Coale, and J. DiGeorge (2010). A new way of looking at contaminants in the Delta--Using the RMA particle tracking model to assess the fate and transport of methyl mercury in the Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Currently about one half of the Delta has top level predator species that are above the EPA human health guidelines for mercury. There are goals by the California Bay Delta Authority to create and restore thousands of acres of wetlands and to drastically alter the structure and functioning of the Delta with additional storage and conveyance (peripheral canals) structures. The effect of these changes on mercury concentrations in water, sediment and fish are unknown. Government managers would like to know what areas of the Delta would increase or decrease in mercury for each of the proposed changes to the Delta. In previous reports a methyl mercury mass balance model was developed but only allowed predictions between the riverine input sites and the export sites of the Delta by lumping all the import sites together and export sites together. In this study the RMA particle tracking model was used to predict the transport routes and fate of methylmercury in sub regions of the Delta. The findings indicate there are major processes including

photodemethylation and sedimentation that occur in the central Delta as opposed to the Sacramento River Channel. The particle transport model could be used to predict how different water conveyance projects and methylmercury control programs would influence fish mercury concentrations. For example, flow or methyl mercury concentrations could be reduced in the model from one of the tributaries and predictions could be made on how the fish would change in mercury concentrations at several downstream areas in the Delta.

Stevens, D. E. (1966). Food habits of striped bass, Roccus saxatilis, in the Sacramento-San Joaquin Delta. Ecological studies of the Sacramento-San Joaquin Delta. Part II. Fishes of the Delta. J. T. Turner, and D.W. Kelley. Sacramento, CA, California Department of Fish and Game, Fish Bulletin 136. 136: 68-96.
This paper describes the food habits of striped bass older than three months, in the Delta of the Sacramento and San Joaquin rivers. Most of the older descriptions (Smith, 1896; Scofield, 1910; Scofield and Coleman, 1910; Scofield and Bryant, 1926; Scofield, 1928, 1931; Shapovalov, 1936; Hatton, 1940; Johnson and Calhoun, 1952) of striped bass food habits in the Sacramento-San Joaquin estuary are merely qualitative or fragmentary. More recently, Heubach, Toth, and McCready (1963) examined a large number of stomachs of bass younger than 6 months from the Delta, but they examined few stomachs of older bass. Ganssle (1966) has described striped bass food habits in the estuary between the Delta and the lower end of San Pablo Bay, and Thomas (1967) has studied the diet of striped bass from the Sacramento and San Joaquin rivers above the Delta down to San Francisco Bay. To avoid duplication of my work, Thomas did not attempt Delta-wide coverage.

Stevens, D. E., and L.W. Miller (1970). "Distribution of sturgeon larvae in the Sacramento-San Joaquin River system." California Fish and Game 56: 80-86.

Stevens, D. E. (1977). Striped bass (Morone saxatilis) monitoring techniques in the Sacramento-San Joaquin Estuary. Proceedings of the Conference on Assessing the Effects of Power-Plant-Induced Mortality on Fish Populations, Gatlinburg, Tennessee, May 3-6, 1977, Pergamon Press.
Various methods have been used to monitor the striped bass population in the Sacramento-San Joaquin Estuary. Sampling in the spring with towed plankton nets has provided an adequate description of spawning time and area, but this sampling has not adequately measured egg standing crops and larva and post-larva mortality rates. Tow-net sampling effectively measures the abundance of young in midsummer. A midwater-trawl survey is satisfactory for measuring the abundance of young in the fall but not in the winter. Techniques have not been fully evaluated for monitoring one-year-old bass. Catch-per-unit-effort data from sportfishing party boats were useful for monitoring two-year-olds, until a change in angling regulations increased recruitment age. The Petersen method and indices developed from party-boat catches are the best methods for monitoring bass that are three years old and older. Long-term trends in catch can be monitored through postcard surveys and party-boat catches..

Stevens, D. E. (1977). "Striped bass (Morone saxatilis) year class strength in relation to river flow in the Sacramento-San Joaquin Estuary, California." Transactions of the American Fisheries Society 106: 34-42.
Striped bass, Morone saxatilis, abundance indices were developed from two analyses of sport-fishing party boat catch statistics for the Sacramento-San Joaquin Estuary. These analyses cover the periods 1938-1954 and 1958-1972. The abundance indices provided evidence that the size of the fishable population fluctuated by a factor of 3.7 during the latter period and that river flows in the first summer of life affected recruitment during both periods

Stevens, D. E. (1979). Environmental factors affecting striped bass (Morone saxatilis) in the Sacramento-San Joaquin estuary. San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 469-478.

Stevens, D. E., and H.K. Chadwick (1979). "Sacramento-San Joaquin Estuary biology and hydrology." Fisheries 4: 2-6.

Stevens, D. E. (1980). Factors affecting the striped bass fisheries of the West Coast. Proceedings of the 5th Marine Recreational Fisheries Symposium, Washington, D.C. USA, Sport Fishing Institute.

Stevens, D. E., and L.W. Miller. (1983). "Effects of river flow on abundance of young chinook salmon, American shad, longfin smelt, and delta smelt in the Sacramento-San Joaquin River system." North American Journal of Fisheries Management 3: 425-437.
Annual abundance indices for young fall-run chinook salmon (Oncorhynchus tshawytscha), American shad (Alosa sapidissima), and longfin smelt (Spirinchus thaleichthys) increased directly with river flow rates during the spawning and nursery periods. Annual abundance of young delta smelt (Hypomesus transpacificus) did not vary with river flow. Several factors associated with flow could explain the relationships described for chinook salmon, American shad, and longfin smelt. The one factor common to all affected species was that dispersal of young increases when flows increase, which probably results in decreased density-dependent mortality.

Stevens, D. E., D.W. Kohlhorst, L.W. Miller, and D.W. Kelley (1985). "The decline of striped bass in the Sacramento-San Joaquin Estuary, California." Transactions of the American Fisheries Society 114: 12-30.
The abundance of young striped bass Morone saxatilis in the Sacramento-San Joaquin Estuary has suffered an unsteady but persistent decline from population levels that were high in the middle 1960s. The decline was particularly severe in 1977 and abundance of young striped bass has been low every subsequent year. The adult striped bass population also has fallen during the past 20 years, but the exact period over which the decline occurred and the rate of decline are not clear. The adult population is now about one-quarter of its former size and there is little sign of recovery. We believe the Sacramento-San Joaquin striped bass population and the fishery that it supports are in serious danger. The cause is most likely one or more of four factors. (1) The adult population is now so low that egg production may be inadequate. (2) The plankton food supply of young striped bass in the western Sacramento-San Joaquin Delta and Suisun Bay has been greatly reduced each spring. Diversion of water from the delta for agricultural purposes is a prime suspect for the decrease in food production. (3) Large numbers of young fish are lost by entrainment in water diversions. (4) The population is stressed by toxic substances such as petrochemicals and pesticides. Additional studies are underway to help determine the principal cause(s) of the striped bass decline.

Stevens, D. E., H.K. Chadwick, and R.E. Painter. (1987). "American shad and striped bass in California's Sacramento-San Joaquin River System." Transactions of the American Fisheries Society 1: 66-78.

Stewart, A. R., S.N. Luoma, and T.S. Presser (2010). Spatial and temporal variation in selenium concentrations in the invasive clam Corbula amurensis in the San Francisco Bay estuary from 1995 to 2010. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Selenium (Se), a naturally occurring trace element, can be mobilized by human activities in sufficient quantities that may threaten fish and wildlife. Efforts to differentiate contributions of local estuarine inputs relative to riverine inputs of Se in the San Francisco Bay and Delta are ongoing. Changing water management strategies and climate change, could alter Se sources and increase Se delivery to the Bay potentially endangering species of concern. Identifying Se sources has been confounded by limited bioaccumulation data in target species that span a range of hydrodynamic and estuarine conditions and models that relate bioaccumulation data to dynamic estuarine processes. As part of the CASCaDE (Computational Assessments of Scenarios of Change for the Delta Ecosystem) and USGS funded projects we are collecting baseline-monitoring data that is being used to develop models that integrate biodynamic and estuarine processes controlling the fate and effects of Se in food webs and in species of concern. Here we present bioaccumulation data for the models under development including fourteen years of Se

concentrations in the invasive clam Corbula amurensis collected monthly at Carquinez Strait, in Suisun Bay and at the convergence of the Sacramento and San Joaquin Rivers. Selenium concentrations in the clams over the period of study ranged from a low of 8.5 to a high of 21.7 μg/g and showed strong spatial and seasonal variation. Significant variation in Se concentrations was also observed among years where values declined from 1997 through 2005 and then increased to near 1997 levels in 2008. We present several hypotheses to explain variation in bioaccumulation data relative to biology and changing estuarine conditions.

Stewart, A. R., S. N. Luoma, et al. (2004). "Food web pathway determines how selenium affects aquatic ecosystems: A San Francisco Bay case study." Environmental Science and Technology 38: 4519-4526.

Chemical contaminants disrupt ecosystems, but specific effects may be under-appreciated when poorly known processes such as uptake mechanisms, uptake via diet, food preferences, and food web dynamics are influential. Here we show that a combination of food web structure and the physiology of trace element accumulation explain why some species in San Francisco Bay are threatened by a relatively low level of selenium contamination and some are not. Bivalves and crustacean zooplankton form the base of two dominant food webs in estuaries, The dominant bivalve Potamocorbula amurensis has a 10-fold slower rate constant of loss for selenium than do common crustaceans such as copepods and the mysid Neomysis mercedis (rate constant of loss, k(e) = 0.025, 0.155, and 0.25 d(-1), respectively). The result is much higher selenium concentrations in the bivalve than in the crustaceans. Stable isotope analyses show that this difference is propagated up the respective food webs in San Francisco Bay. Several predators of bivalves have tissue concentrations of selenium that exceed thresholds thought to be associated with teratogenesis or reproductive failure (liver Se > 15 mug g(-1) dry weight). Deformities typical of selenium-induced teratogenesis were observed in one of these species. Concentrations of selenium in tissues of predators of zooplankton are less than the thresholds. Basic physiological and ecological processes can drive wide differences in exposure and effects among species, but such processes are rarely considered in traditional evaluations of contaminant impacts.

Stewart, I. T., D. R. Cayan, et al. (2004). "Changes in snowmelt runoff timing in western North America under a 'business as usual' climate change scenario." Climatic Change 62(1-3): 217-232.

Spring snowmelt is the most important contribution of many rivers in western North America. If climate changes, this contribution may change. A shift in the timing of springtime snowmelt towards earlier in the year already is observed during 1948 - 2000 in many western rivers. Streamflow timing changes for the 1995 - 2099 period are projected using regression relations between observed streamflow-timing responses in each river, measured by the temporal centroid of streamflow (CT) each year, and local temperature (TI) and precipitation (PI) indices. Under 21st century warming trends predicted by the Parallel Climate Model (PCM) under business-as-usual greenhouse-gas emissions, streamflow timing trends across much of western North America suggest even earlier springtime snowmelt than observed to date. Projected CT changes are consistent with observed rates and directions of change during the past five decades, and are strongest in the Pacific Northwest, Sierra Nevada, and Rocky Mountains, where many rivers eventually run 30 - 40 days earlier. The modest PI changes projected by PCM yield minimal CT changes. The responses of CT to the simultaneous effects of projected TI and PI trends are dominated by the TI changes. Regression-based CT projections agree with those from physically-based simulations of rivers in the Pacific Northwest and Sierra Nevada.

Stewart, I. T., D. R. Cayan, et al. (2005). "Changes toward earlier streamflow timing across western North America." Journal of Climate 18(8): 1136-1155.

The highly variable timing of streamflow in snowmelt-dominated basins across western North America is an important consequence, and indicator, of climate fluctuations. Changes in the timing of snowmelt-derived streamflow from 1948 to 2002 were investigated in a network of 302 western North America gauges by examining the center of mass for flow, spring pulse onset dates, and seasonal fractional flows through trend and principal component analyses. Statistical analysis of the streamflow timing measures with Pacific climate indicators identified local and key

large-scale processes that govern the regionally coherent parts of the changes and their relative importance. Widespread and regionally coherent trends toward earlier onsets of springtime snowmelt and streamflow have taken place across most of western North America, affecting an area that is much larger than previously recognized. These timing changes have resulted in increasing fractions of annual flow occurring earlier in the water year by 1-4 weeks. The immediate (or proximal) forcings for the spatially coherent parts of the year-to-year fluctuations and longer-term trends of streamflow timing have been higher winter and spring temperatures. Although these temperature changes are partly controlled by the decadal-scale Pacific climate mode [Pacific decadal oscillation (PDO)], a separate ani significant part of the variance is associated with a springtime warming trend that spans the PDO phases.

Stillman, J. (2010). Metabolic responses to environmental salinity in the invasive clam Corbula amurensis. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Stoms, D. M. (2010). "Change in Urban Land Use and Associated Attributes in the Upper San Francisco Estuary, 1990 to 2006." San Francisco Estuary and Watershed Science 8(3).

Land use is an ultimate driver of many of the stressors on the Upper San Francisco Estuary, but the magnitude and pattern of land use change has not been analyzed. This paper attempts to fill this knowledge gap through a screening-level risk assessment. Urban land use was compared within hydrodynamic subregions in 1990, 2000, and 2006. Ancillary data were then used to quantify secondary measures such as impervious cover, housing density, road density and road crossings. Despite the rapid growth of the Bay Area, Sacramento, and Stockton metropolitan areas, the percentage of urban area and rates of change in the subregions are generally low to moderate when compared to other estuaries in the United States. The spatial data sets used in this analysis have been posted online to a public repository to be used by other researchers.

Stralberg, D., J. Wood, M. Fitzgibbon, D. Jongsomjit, S. Crooks, M. Brennan, L. Schile, J. Callaway, and V.T. Parker (2010). Spatial climate change scenarios for San Francisco Bay tidal marsh habitats. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Climate change will affect wetlands in San Francisco Bay through sea-level rise and seasonal salinity increases. These changes are likely to convert tidal freshwater and brackish wetlands into more fragmented saline systems and result in greater inundation of tidal marshes, changing plant species composition and habitat structure for birds and other wildlife. To implement effective conservation strategies, we must understand the potential landscape-scale effects of climate change on tidal marshes and the birds that depend on them. We adapted a dynamic marsh accretion model to non-linear sea-level rise projections to develop spatially explicit projections (maps) of tidal marsh extent and elevation in 20-year intervals over the next 100 years. Using these projections in combination with projected changes in salinity, we modeled potential change in the tidal-marsh plant community. Drawing upon our knowledge of bird and plant associations, we modeled potential changes in the distributions of tidal marsh birds of conservation concern. To provide detailed information to land managers, conservation planners and policy makers, we have developed summaries and web-based decision-support tools to allow users to interactively 1) assess and query the potential effects of climate change on tidal marsh habitats, plants, and bird populations under various scenarios of sediment availability, salinity, sea-level rise, and levee condition, and 2) identify priority sites for wetland conservation and restoration. The primary objective of this tool is to facilitate conservation of tidal-marsh habitat in the context of a rapidly changing environment. Initial results show that the vertical accretion rates necessary for tidal marshes to keep pace with sea-level rise are strongly affected by our regional assumptions of future sediment availability. In addition, we found that the potential for landward tidal marsh migration will likely be extremely limited due to topographic and anthropogenic constraints.

Street, J., A.L. Sessions, R.S. Anderson, and A. Paytan (2010). Holocene hydrologic variability in the western Sierra Nevada from D/H ratios in leaf waxes. 6th Biennial

Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Large-scale atmospheric circulation patterns and underlying ocean conditions in the Northeastern Pacific have a strong bearing on continental climate and water availability in California, as demonstrated in the past century of instrumental measurements. However, the nature of the relationship between ocean-atmosphere processes and hydrologic variability in the Sacramento-San Joaquin watershed draining the Sierra Nevada remains unclear on timescales greater than a few decades, and during past climate regimes of the Holocene. The 20,000-yr sedimentary record recovered from Swamp Lake, a mid-elevation (1554 m) lake in Yosemite NP, provides a rare opportunity to reconstruct hydrologic variability in the central Sierra at <100 yr resolution in relation to known or theorized regime shifts in the North Pacific and global drivers of climate. Here we present the results of organic geochemical and isotopic analyses of sedimentary organic matter from a 10 m core from the deep basin of Swamp Lake. In particular, we explore the utility of compound-specific hydrogen isotope (D/H) measurements on leaf-wax n-alkanes extracted from the sediment as a hydrologic tracer. Our results indicate that leaf-wax D/H ratios are most sensitive to changes in the lake water balance and the size of the spring snowpack, which over time have responded to atmospheric circulation changes on multiple timescales. A long-term, Holocene-spanning decline in D/H of terrestrial leaf waxes reflected a gradual increase in cool season (Dec-Feb) precipitation driven by insolation changes. Distinct multi-century oscillations in D/H occurring over the last ~12 kyr were coincident with both circulation regime shifts and drought cycles in California. Increased amplitude and frequency of D/H variability over the past ~6000 years paralleled the development of modern ENSO cycles in the tropical Pacific. The reconstructed changes in both the mean state and variability of Sierra Nevada hydroclimate over the Holocene may provide insight into water availability during 21st century climate warming.

Strong, C. M., L. B. Spear, et al. (2004). "Forster's Tern, Caspian Tern, and California Gull Colonies in San Francisco Bay: Habitat Use, Numbers and Trends, 1982-2003." Waterbirds 27(4): 411-423.

We analyzed data on numbers and annual trends of breeding terns and gulls based on censuses of all colonies of the Caspian Tern (Sterna caspia), Forster's Tern (S. forsteri) and California Gull (Larus californicus) in the San Francisco Bay estuary from 1982 to 2003. All species used nesting substrates that were flat, largely non-vegetated, had a wide view in all directions, and were composed of sand, gravel, or earth. The estuary supported 17, 13, and seven colonies of each species, respectively. Nesting terns were primarily on salt evaporation pond islands and tidal islands. The largest colony of California Gulls was on a deactivated salt pond. Total numbers of each species in 2003 were about 2,300, 2,450 and 21,200 breeding birds, respectively. Numbers of Forster's Terns declined significantly during the study, while California Gulls increased, and the number of Caspian Terns was stable. Numbers of each species at each colony site have shown considerable annual variation. We attribute the lack of colony site fidelity of each species, and the decline among Forster's Terns, primarily to mammalian predation, human disturbance, and possibly annual variation in food availability. Flat, minimally vegetated islands, which are few in the estuary, are critical for maintaining nesting terns and California Gulls. Yet, the planned restoration of 65% (9,050 ha) of the salt pond complex of the San Francisco Bay estuary will likely remove some of the salt pond islands and levees where 20% of the Caspian Terns (438 birds), 80% of Forster's Terns (1,958) and 96% of California Gulls (20,210) were nesting in 2003. We recommend that restoration plans should include the creation of sizeable tracts of islands specifically designed to provide nesting habitat for these larids. These replacement sites should be in place soon after the restoration has been implemented; i.e., well before scheduled completion. This is especially important because severe habitat limitation would lead to competition for nesting space among the three species, a situation expected to result in exclusion of the terns by the gull, which nests earlier, are larger, more abundant, and more aggressive.

Strong, C. R. and S. N. Luoma (1981). "Variations in the Correlation of Body Size With Concentrations of Cu and Ag in the Bivalve Macoma balthica." Canadian Journal of Fisheries and Aquatic Sciences 38(9): 1059-1064.

The relationship between body size and concentrations of Cu and Ag varied from strongly positive to strongly negative in four populations of the bivalve Macoma balthica in San Francisco Bay. The correlations appeared to be influenced by the degree of enrichment in tissue, size-dependent differences and seasonal variations in growth rate, and size-dependent differences in uptake rates. The use of benthic indicator organisms to assess metal contamination requires understanding the relationship between metal concentration and body size at least within each population, and in some cases within each sample from each population.

Sukardi, M. (2010). Streamflows of San Francisco Bay Tributaries, Water Years 2008 and 2009. IEP Newsletter. 23: 2.

Sullivan, L., W. J. Kimmerer, and J. Lindberg (2010). Feeding, growth, and survival of larval delta smelt: impacts of introduced prey. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Populations of planktivorous fish in the San Francisco Estuary (SFE) are in a state of decline. Declines in several species have been correlated to changes in the abundance and distribution of their zooplankton prey. These correlations provide indirect evidence that changes in food supply are contributing to the decrease in fish abundance. Over the past two decades, there has been a shift in the species composition of zooplankton from a community dominated by numerous species of calanoid copepods to one dominated by a single introduced cyclopoid copepod, Limnoithona tetraspina. Since its introduction, L. tetraspina has become the most abundant copepod, at times outnumbering all other copepods by a factor of ten. Additionally, because L. tetraspina is approximately 1/20th the biomass of the historically dominant calanoid species (i.e., Eurytemora affinis and Pseudodiaptomus forbesi), there has been a corresponding decline in the accessibility and total biomass of available prey. To test for an effect of prey type on growth and survival of delta smelt (Hypomesus transpacificus), we conducted long-term rearing trials with first-feeding (6 days old) and 30-day-old larvae. Each age-group was reared for 30 days on one of three diets: cyclopoid copepods (L. tetraspina), calanoid copepods (P. forbesi) or a control diet (rotifers and Artemia sp.). Field-collected zooplankton were size fractionated appropriately for each age-group of fish tested. Each prey category was offered in excess but at relative densities similar to those observed in situ. Both age-groups of larvae grew faster (fork length) when fed P. forbesi than L. tetraspina; however, larval survival did not differ significantly among diets. This information supports claims that high abundances of L. tetraspina may provide suboptimal nutrition to the delta smelt population, and that this shift in prey composition may be contributing to the decline of pelagic organisms in the SFE.

Sullivan, M., and T. Jabusch (2010).
Delta RMP: Developing the Delta Regional Monitoring Program for contaminants. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Swanson, C., R.C. Mager, S.I. Doroshov, and J.J. Cech, Jr. (1996). "Use of salts, anesthetics, and polymers to minimize handling and transport mortality in delta smelt." Transactions of the American Fisheries Society 125(2): 326-329.

We tested the effects of transport containers and transport water treatments on the survival of field-collected delta smelt Hypomesus transpacificus, a threatened osmerid endemic to the Sacramento-San Joaquin estuary in California. Use of cylindrical polyethylene bags instead of rectangular coolers as transport containers increased survival from 40.7 to 83.6% at 4 h postcollection, from 11.9 to 33.1 % at 48 h, and from 6.9 to 27.9% at 72 h. Addition of NovAqua, a commercial water conditioner containing polymers, to transport water of 8‰ NaCl significantly increased 72-h survival (54.8%) over that of the 8‰ NaCl control (27.9%). Survival of fish lightly anesthetized with MS-222 (tricaine methanesulfonate) during transport was intermediate between the NaCl and NaCl plus NovAqua treatments. Survival of delta smelt in the NaCl plus NovAqua treatment also improved from August through November, as fish increased in size and water temperature decreased. Improved survival of delta smelt treated with NovAqua was probably related to the

polymers, which may have reduced physiological stress responses, such as osmotic imbalance.

Swanson, C., P.S. Young, and J.J. Cech. (1998). "Swimming performance of delta smelt: maximum performance, and behavioral kinematic limitations on swimming at submaximal velocities." Journal of Experimental Biology 201: 333-345.
Swimming performance, measured as critical swimming velocity (Ucrit) and endurance, and swimming behavior and kinematics were measured in delta smelt Hypomesus transpacificus, a threatened estuarine planktivore. Most fish (58 % of the Ucrit test group) were capable of achieving and sustaining moderately high velocities: mean Ucrit was 27.6+5.1 cm s-1 (s.d.). Ucrit was not affected by either acclimation temperature (12-21 C) or fish size (3.2-6.8 cm standard length) and was generally comparable with values measured for other similarly sized fishes. The remaining 42 % of the fish failed to swim at velocities above 10-15 cm s-1. Interestingly, of the fish that provided a Ucrit measurement, 62 % experienced at least one temporary swimming failure between 10 and 20 cm s-1. Endurance was highly variable and, for all velocities, not normally distributed; the only significant decrease, from 6 h to 64 min, occurred between 10 and 15 cm s-1. Kinematic analyses of stroke frequency, stroke amplitude, stride length, glide frequency, glide duration, proportion of time spent stroking and the number of strokes between successive glides showed that delta smelt employed three velocity-dependent swimming gaits: a discontinuous 'stroke-and-glide' swimming behavior below 10 cm s-1; a continuous swimming behavior above 15 cm s-1 and up to Ucrit; and a discontinuous 'burst-and-glide' swimming behavior at velocities above Ucrit. Swimming failure at velocities between 10 and 20 cm s-1 coincided with the transition from 'stroke-and-glide' swimming to continuous swimming; delta smelt were unable or unwilling to swim steadily in the flume within this transition velocity range. These results underscore the importance of monitoring and quantifying behavior in experiments intended as physiological performance tests of whole animals.

Swanson, C., T. Reid, P.S. Young, and J.J. Cech. (2000). "Comparative environmental tolerances of threatened delta smelt (Hypomesus transpacificus) and introduced wakasagi (H. nipponensis) in an altered California estuary." Oecologia 123(3): 384-390.
In California's Sacramento-San Joaquin estuary, environmental protection and habitat restoration efforts directed at a threatened native osmerid, the delta smelt (Hypomesus transpacificus), are complicated by the presence of a morphologically similar non-native congener, the wakasagi (H. nipponensis), transported to the estuary from upstream reservoirs. In order to better define delta smelt critical habitat and to evaluate the potential for habitat overlap by these two species, we compared the tolerances of the two species to temperature, salinity, and water velocity, environmental factors that vary spatially and temporally within the estuary. For fishes acclimated to 17°C and fresh water (0 ppt), we measured critical thermal maxima and minima, chronic upper salinity tolerance limits, and critical swimming velocities. Wakasagi had higher critical thermal maxima (29.1°C vs. 25.4°C for delta smelt), lower critical thermal minima (2.3°C vs. 7.5°C for delta smelt), higher upper salinity tolerances (26.8 ppt vs. 19.1 ppt for delta smelt), and swam faster (for 6–6.9 cm SL fish, 43.3 cm s–1 vs. 28.2 cm s–1 for delta smelt) than delta smelt. This suggests that the wide seasonal and year-to-year fluctuations in temperature, salinity, and flow typical in the estuary would not exclude wakasagi, although their eggs and larvae may be less tolerant. With respect to these factors, the native delta smelt may be at a physiological disadvantage, particularly in habitats with suboptimal environmental conditions, and may be excluded from shallow-water habitat restoration sites, which are characterized by poor circulation, low flows, and more environmentally extreme conditions. The low abundance of wakasagi in the estuary recorded to date may indicate that factors other than temperature, salinity, and flow determine wakasagi distribution.

Swanson, C., J. Rosenfield, and G. Bobker (2010). Developing flow criteria to protect public trust resources in the Sacramento-San Joaquin Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Flow is the key physical and ecological driver in riverine and estuarine

ecosystems. In California’s Sacramento-San Joaquin watershed and its Delta, flows are highly altered and intensively managed for water storage and diversion. The intensity of water management activities has increased steadily during the past fifty years and there is now substantial scientific evidence that these flow alterations have contributed to both long-term and recent population declines of native fish species by degrading habitat conditions and providing favorable conditions for invasive species. In response to the SWRCB’s request for information regarding flows necessary to protect ecosystem and fishery resources, we developed quantitative recommendations for four flow parameters: Delta outflow, inflows from the Sacramento and San Joaquin basins, and in-Delta hydrodynamic conditions. Our recommendations were designed to promote adequate levels of four population viability criteria: abundance, productivity, diversity and spatial structure. We used statistical, mechanistic and retrospective historical analyses of the relationships between flow and the viability criteria to identify flow levels needed to support viable populations of public trust species. Numerous other stressors may contribute to recent declines of fish populations that use the Delta but the effects of altered flow regimes exacerbates each of them. We assumed that, where necessary, additional actions were taken to address other known stressors; thus, our recommendations are for flows necessary to protect the public trust if these other stressors are completely mitigated. Based on these analyses, we recommended increases in winter-spring Delta outflows and Sacramento and San Joaquin River inflows during appropriate months and seasons. We also recommended improved Delta hydrodynamic conditions (positive Old and Middle River flows). These recommendations were tied to specific population viability objectives for key species.

Swanson, C., D. V. Baxa, et al. (2002). "Reduced swimming performance in delta smelt infected with Mycobacterium spp." Journal of Fish Biology 61(4): 1012-1020.

Swanson, C., P. S. Young, et al. (2005). "Close encounters with a fish screen: Integrating physiological and behavioral results to protect endangered species in exploited ecosystems." Transactions of the American Fisheries Society 134(5): 1111-1123.
Protection of endangered species that are restricted to highly modified ecosystems and threatened by anthropogenic activities often includes regulatory design and operational criteria for structures and facilities located within the species' critical habitat. In many freshwater systems, loss of fishes at water diversions has contributed to population declines of multiple species. Fish screens prevent removal of fish from the habitat; however, under current design criteria, the degree of protection provided by screens is unknown for most affected species. We used a large laboratory-based flume to observe and quantify the responses of delta smelt Hypomesus transpacificus, an endangered osmerid threatened by water diversions in California's Sacramento-San Joaquin Estuary, to a simulated fish screen. For a range of flow and environmental conditions, we measured screen contact frequency, swimming behavior, injuries, and survival. Delta smelt experienced frequent temporary contact with the screen, and contact rates were influenced by flow and time of day-light level. Contact was injurious, and postexperiment mortality rates were directly related to both contact frequency and severity as well as temperature. Quantitative models showed that, for this species, both behavioral responses such as swimming velocity and physiological responses to fish screen contact, as modified by environmental conditions, controlled the species' performance and its risk from the diversion and the screen. The results illustrate that ecologically effective protection strategies and regulatory criteria developed on the basis of multiple integrated responses of the organism to the stressor offer greater benefits and certainty to both the organism and the regulated activities.

Swanson, C. P. S. Y., P. S., J.J. Cech Jr. (1999). Swimming behavior of delta smelt in multivector flow regimes: Applications for fish screens. Fish Performance Studies. D. MacKinlay, K. Howard and J. Cech, Jr.: 115-119.
The delta smelt, Hypomesus transpacificus, is a small osmerid found only in California's Sacramento-San Joaquin estuary. Following a drastic population decline in the early 1980s and continuing low population levels, the species was listed as threatened under both federal and state Endangered Species Acts. Entrainment and

impingement losses of larval, juvenile, and adult fish at the more than 2200 screened and unscreened water diversions located within its habitat have contributed to the delta smelt's decline. Detailed investigations of delta smelt swimming in unidirectional flows in a Brett-type flume indicated that the fish are moderate swimmers with distinct velocity-dependent swimming behaviours and both behavioral and kinematic limitations on swimming at submaximal velocities. Given the importance of the behavioural component in delta smelt swimming, application of results of this type of study to develop safe flow criteria for screened water diversions was problematic and might seriously misinterpret the fish's true performance in flowing water near the fish screens. The objective of this study was to examine delta smelt swimming behavior and performance in multi-vector flows similar to those that occur near screened water diversions.

Swanson, K., J.Z. Drexler, D.H. Schoellhamer, K.M. Thorne, K.A. Spragens, and J.Y. Takekawa (2010). Integrating biological and physical processes to predict the impact of sea-level rise on tidal marsh habitat. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
The San Francisco Bay Estuary contains the largest extent of tidal marsh in the western United States and is home to several state and federally listed threatened and endangered species. Climate change threatens these habitats through accelerated sea-level rise. These wetlands are sustained when the rate of relative sea-level rise is less than or in equilibrium with organic and inorganic inputs to the marsh surface. The Wetland Accretion Rate Model for Ecosystem Resilience, or WARMER, a 1-D model of elevation at a point representative of wetland habitat that incorporates both biological and physical processes of vertical marsh accretion, is currently being developed in order to better understand the threat of rising sea level on marsh sustainability. Processes included in the model are inorganic sediment deposition and organic matter production, decomposition, and compaction. WARMER builds upon existing wetland vertical accretion models by incorporating more realistic tidal forcing and sediment deposition processes as well as including a more realistic biomass production routine. The model will be applied to marshes across the San Francisco Bay Estuary in conjunction with wildlife monitoring as part of the USGS National Climate Change and Wildlife Science Center Project. Results will be used to evaluate the likely effect of sea-level rise on the elevation of habitat used by endangered and threatened species and the potential for these habitats to be drowned. This poster will present the theoretical framework for the model and describe how the model will be applied to various marsh habitats throughout the San Francisco Bay Estuary.

Swartz, R. C., F. A. Cole, et al. (1994). "Sediment toxicity, contamination and amphipod abundance at a DDT-and dieldrin-contaminated site in San Francisco Bay." Environmental Toxicology and Chemistry 13(6): 949-962.
Sediment toxicity to the amphipod Eohaustorius estuarius, sediment contamination, and the abundance of amphipods were examined along a contamination gradient in the Lauritzen Channel and adjacent parts of Richmond Harbor, California. Dieldrin and DDT were formulated and ground at this site from 1945 to 1966. Sediment contamination by both dieldrin and the sum of DDT and its metabolites (sigma DDT) was positively correlated with sediment toxicity and negatively correlated with the abundance of amphipods excluding Grandidierella japonica. The maximum dieldrin and sigma DDT concentrations in toxic units were 0.018 and 9.43, respectively, indicating that sigma DDT was the dominant ecotoxicological factor. Concentrations of PAHs, PCBs, and metals were not sufficient to cause appreciable toxicity, except at one PAH-contaminated station. Relations between sigma DDT, sediment toxicity, and amphipod abundance are similar at three sigma DDT-contaminated sites. The 10-d LC50 for sigma DDT in field-collected sediment was 2,500 mu g/g organic carbon (OC) for Eohaustorius estuarius in this study, 1,040 mu g/g OC for Rhepoxynius abronius exposed to Palos Verdes Shelf, California, sediment, and 2,580 mu g/g OC for Hyalella azteca exposed to sediment from a freshwater stream system near Huntsville, Alabama. The threshold for 10-d sediment toxicity occurred at about 300 mu g sigma DDT/g OC. The abundance of amphipods (except Grandidierella japonica) was reduced at sigma DDT concentrations >100 mu g/g OC. Correlations between toxicity, contamination, and biology indicate that acute sediment toxicity to Eohaustorius estuarius, Rhepoxynius abronius, or Hyalella azteca in lab tests provides reliable

evidence of biologically adverse sediment contamination in the contamination in the field.

Sweetnam, D. A. (1999). "Status of delta smelt in the Sacramento-San Joaquin Estuary." California Fish and Game 85(1): 22-27.

Swift, T., J. Christen, S. San Julian, B. Suits, and B. Giorgi (2010). California DWR's Real-Time Data and Forecasting Project: Linking water quality monitoring, modeling, and communication. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
There is a compelling and ongoing need to monitor, understand, and –as much as possible– predict and manage water quality in the Delta and the processes that affect it. The Delta is the source for much of the drinking water in California, and detailed knowledge of Delta water quality helps municipal water treatment operators manage treatment to comply with drinking water regulations while minimizing costs. There is also an ongoing need for detailed Delta water quality data to understand the Delta's dynamic ecological processes. The California Department of Water Resources together with the State Water Contractors have developed the Real Time Data and Forecasting (RTDF) program. The RTDF program consists of three interrelated efforts; Field monitoring, modeling and forecasting, and data dissemination. The goal of the project is to help municipal water supply providers with tools to make informed decisions in response to sudden changes in source water quality in the Sacramento-San Joaquin Delta and State Water Project. Monitoring includes several permanent remote stations that measure organic carbon, anions, and other water quality parameters in real time and send results to a central server. Modeling and forecasting is a collaboration between modeling groups within DWR that produce volume, conductivity, and organic carbon source water tracking, as well as conductivity forecasts. Data dissemination includes real-time data posted to the web, and daily and weekly emailed water quality newsletters discussing trends, causes, and forecasts. RTDF data and information are organized in user-friendly formats to meet the needs of a diverse audience of municipal water quality managers, scientists, and other interested parties. We review recent advances, findings, and lessons learned from the program.

Tabor, R. A., B.A. Footen, K.L. Fresh, M.T. Celedonia, F. Mejia, D.L. Low, and L. Park (2007). "Smallmouth bass and largemouth bass predation on juvenile chinook salmon and other salmonids in the Lake Washington Basin." North American Journal of Fisheries Management 27(4): 1174-1188.
We assessed the impact of predation by smallmouth bass Micropterus dolomieu and largemouth bass M. salmoides on juveniles of federally listed Chinook salmon Oncorhynchus tshawytscha and other anadromous salmonid populations in the Lake Washington system. Bass were collected with boat electrofishing equipment in the south end of Lake Washington (February–June) and the Lake Washington Ship Canal (LWSC; April–July), a narrow waterway that smolts must migrate through to reach the marine environment. Genetic analysis was used to identify ingested salmonids to obtain a more precise species-specific consumption estimate. Overall, we examined the stomachs of 783 smallmouth bass and 310 largemouth bass greater than 100 mm fork length (FL). Rates of predation on salmonids in the south end of Lake Washington were generally low for both black bass species. In the LWSC, juvenile salmonids made up a substantial part of bass diets; consumption of salmonids was lower for largemouth bass than for smallmouth bass. Smallmouth bass predation on juvenile salmonids was greatest in June, when salmonids made up approximately 50% of their diet. In the LWSC, overall black bass consumption of salmonids was approximately 36,000 (bioenergetics model) to 46,000 (meal turnover consumption model) juveniles, of which about one-third was juvenile Chinook salmon, one-third was coho salmon O. kisutch, and one-third was sockeye salmon O. nerka. We estimated that about 2,460,000 juvenile Chinook salmon (hatchery and wild sources combined) were produced in the Lake Washington basin in 1999; thus, the mortality estimates in the LWSC range from 0.5% (bioenergetics) to 0.6% (meal turnover). Black bass prey mostly on subyearlings of each salmonid species. The vulnerability of subyearlings to predation can be attributed to their relatively small size; their tendency to migrate when water temperatures exceed 15°C, coinciding with greater black bass activity; and their use of nearshore areas, where overlap with black bass is

greatest. We conclude that under current conditions, predation by smallmouth bass and largemouth bass has a minor impact on Chinook salmon and other salmonid populations in the Lake Washington system.

Takabayashi, M., K. Lew, et al. (2006). "The effect of nutrient availability and temperature on chain length of the diatom, Skeletonema costatum." Journal of Plankton Research 28(9): 831-840.
We determined the effects of temperature and nutrients on the chain length of a diatom, Skeletonema costatum, in batch culture and enclosure experiments with estuarine water from San Francisco Bay, USA, using the recently developed CytoBuoy flow cytometer. Determination of the number of cells per diatom chain by CytoBuoy flow cytometer and associated software correlated well with but was much more precise and time efficient than microscopic quantification. Increasing temperatures (from 6, 8 to 17{degrees}C) and nutrient concentrations induced high growth rates and dominance by longer chains in a cultured S. costatum strain that was originally acclimatized to a temperature range of 11-30{degrees}C. Similarly, a positive correlation between growth rate and chain length was observed in S. costatum in batch culture and natural communities in enclosure experiments. Maximal chain lengths of S. costatum were greater in natural populations than in the batch culture. Longer chains affect sinking rates and thus likely help the diatom remain suspended in the upper part of the water column where physical and chemical parameters are more favorable for growth.

Takekawa, J. Y., A.K. Miles, N.D. Athearn, S.E. Spring, M.K. Saiki, F. Mejia, I. Woo, and K.S. Goodenough (2005). Habitat restoration monitoring for the Napa-Sonoma Marsh Restoration Project, 2005. Vallejo, U.S. Geological Survey: 78 pp.

Takekawa, J. Y., A.K. Miles, D.H. Schoellhamer, B. Jaffe, N.D. Athearn, S.E. Spring, G.G. Shellenbarger, M.K. Saiki, F. Mejia, and M.A. Lionberger (2005). South Bay Salt Ponds Restoration Project: Short-term data needs, 2003-2005. Vallejo, U.S. Geological Survey: 270 pp.

Takekawa, J. Y., K. Thorne, K. Spragens, D.H. Schoellhamer, J. Drexler, K. Swanson, M. Casazza, and C. Overton (2010). Evaluating the effects of projected sea-level rise on endemic tidal marsh species in San Francisco Bay estuary; an interdisciplinary approach. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Coastal salt marshes and estuaries are projected to be disproportionately impacted by climate change and sea level rise, according to projections by the Intergovernmental Panel on Climate Change. Over 80% of wetlands in San Francisco Bay estuary have been lost to urban development and landscape modification. The San Francisco Bay estuary, though severely fragmented and modified, represents the largest remaining habitat for federally and state listed species. Projected sea-level rise could pose synergistic effects. Maintenance of habitat is crucial to the success of endangered species, but it remains unknown how sea level rise may impact the amount and quality of habitat for these species. Our goal in this ongoing research is to provide information to resource and land managers charged with the protection of endangered species and their habitats that are in need of regional and site-specific data to anticipated climate change impacts to their lands. A total of 13 San Francisco Bay salt marsh sites are included in this study. Changing sediment loads, extreme tide and storm events, salinities, and sea level rise will affect tidal marshes by altering the plant community composition and structure that provide the critical habitat for these endemic species. Our on going interdisciplinary study objectives are to: (1) develop high resolution elevation models using a RTK GPS of the tidal salt marshes and project effects of sea level rise and identify potential critical thresholds for vertebrate species; (2) model sediment geomorphic characteristics to evaluate marsh persistence through time; and (3) downscale tidal cycles to assess site-specific inundation patterns in the local marshes. We will be presenting our USGS National Climate Change Wildlife Science Center ongoing funded work in San Francisco Bay.

Takekawa, J. Y., C. T. Lu, et al. (2001). "Avian communities in baylands and

artificial salt evaporation ponds of the San Francisco Bay estuary." Hydrobiologia 466: 1-3.
San Francisco Bay wetlands, seasonal and tidal marshes between the historic low and high tide lines, are now highly fragmented because of development during the past 150 years. Artificial salt pond systems in the Bay are hypersaline and typically support simple assemblages of algae and invertebrates. In order to establish the value of salt ponds for migratory waterbirds, we used datasets to conduct a meta-analysis of avian communities in the baylands and salt ponds of San Pablo Bay. Fifty-three species of waterbirds in the salt ponds represented six foraging guilds: surface feeders, shallow probers, deep probers, dabblers, diving benthivores and piscivores. The total number of species and the Shannon-Weiner diversity index was higher in baylands than in salt ponds during all four seasons. However, overall bird density (number/ha) was higher in salt ponds compared with baylands in the winter and spring, primarily because of large concentrations of benthivores. Cessation of salt production in 1993 and subsequent reduction in water depth resulted in a decline of some diving duck populations that used the salt ponds.

Takekawa, J. Y., A. K. Miles, et al. (2006). "Trophic structure and avian communities across a salinity gradient in evaporation ponds of the San Francisco Bay estuary." Hydrobiologia 567: 307-327.
Commercial salt evaporation ponds comprise a large proportion of baylands adjacent to the San Francisco Bay, a highly urbanized estuary. In the past two centuries, more than 79% of the historic tidal wetlands in this estuary have been lost. Resource management agencies have acquired more than 10 000 ha of commercial salt ponds with plans to undertake one of the largest wetland restoration projects in North America. However, these plans have created debate about the ecological importance of salt ponds for migratory bird communities in western North America. Salt ponds are unique mesohaline (5-18 g l(-1)) to hyperhaline (> 40 g l(-1)) wetlands, but little is known of their ecological structure or value. Thus, we studied decommissioned salt ponds in the North Bay of the San Francisco Bay estuary from January 1999 through November 2001. We measured water quality parameters (salinity, DO, pH, temperature), nutrient concentrations, primary productivity, zooplankton, macroinvertebrates, fish, and birds across a range of salinities from 24 to 264 g l(-1). Our studies documented how unique limnological characteristics of salt ponds were related to nutrient levels, primary productivity rates, invertebrate biomass and taxa richness, prey fish, and avian predator numbers. Salt ponds were shown to have unique trophic and physical attributes that supported large numbers of migratory birds. Therefore, managers should carefully weigh the benefits of increasing habitat for native tidal marsh species with the costs of losing these unique hypersaline systems.

Takekawa, J. Y., S. E. Wainwright De La Cruz, et al. (2002). "Relating Body Condition to Inorganic Contaminant Concentrations of Diving Ducks Wintering in Coastal California." Archives of Environmental Contamination and Toxicology 42(1): 60-70.
In wild waterfowl, poor winter body condition may negatively affect migration, survival, and reproduction. Environmental contaminants have been shown to adversely affect the body condition of captive birds, but few field studies have examined body condition and contaminants in wild birds during the winter. We assessed the body condition of carcasses from a collection of canvasbacks (Aythya valisineria) and lesser (A. affinis) and greater scaup (A. marila) wintering in coastal California. We used Akaike information criterion (AIC) to select the model with the best balance of parsimony and goodness of fit that related indices of body condition with concentrations of Cd, Cu, Hg, Se, and Zn. Total ash-free protein in canvasbacks decreased with increasing Se concentrations, and pancreas mass decreased with increasing Hg. We combined the closely related lesser and greater scaup in analyses and found that total carcass fat, pancreas mass, and carcass mass decreased with increasing Zn concentrations, and pancreas mass decreased with increasing Hg. Our AIC analysis indicated that some indices of body condition in diving ducks were inversely related to some environmental contaminants in this collection, but additional AIC analyses should be conducted across a wider range of contaminant concentrations to corroborate our findings.

Takekawa, J. Y., N. Warnock, et al. (2002). "Waterbird use of Bayland Wetlands in the San Francisco Bay estuary: Movements of long-billed Dowitchers during the winter." Waterbirds 25: 93-105.

The San Francisco Bay estuary is a migration and wintering area for more than 1.5 million waterbirds on the west coast of North America. Because the estuary is located in a metropolitan area, development and diking of baylands (the region between the edge of the bay and the historical high tide line) have greatly altered the wetland landscape. Recently, conservation interests have promoted restoration of diked baylands to tidal salt marshes for the benefit of endangered native species. However, effects of tidal marsh conversion Oil the existing community of waterbirds in the baylands are largely unknown, especially, in muted tidal marshes with restricted inflows and in artificial salt evaporation ponds where high waterbird densities are found The first radio-marking study of the Long-billed Dowitcher (Limnodromus scolopaceus) was conducted in November-December 2000 to examine their use of baylands. We captured 32 birds by rocket netting in a muted tidal marsh on the North Bay and radio-marked them with 1.2 g transmitters affixed With glue. Individuals Were tracked for all average of 20.3 d (+/- 8.5 SD) and obtained 217 high tide and 195 low tide locations. Movements between tides (x = 1.29 +/- 1.48 SD km) and home range sizes ((x) over bar = 17.7 +/- 16.0 SD km(2)) were highly variable. Long-billed Dowitchers preferred open habitats Such as muted tidal marshes during the high tide, but the majority (78.5%) also remained ill these wetlands during low tide rather than feeding at nearby Fund flats. Their avoidance of mud flats contrasted sharply with Western Sandpipers (Calidris mauri) but was similar to Black-necked Stilts (Himantopus mexicanus). Seven Long-billed Dowitchers flew 110 km inland to Central Valley wetlands in mid-December, a regional movement documented earlier for Dunlin (Calidris alpina) wintering on the coast. However, unlike Dunhill, their Movements were not in response to rainfall but may have been in response to a low pressure front or possibly predictable flooding of Fields in the Central Valley. Although the estuary is a major wintering area supporting large numbers of waterbuds, some birds such as Long-billed Dowitchers move inland to freshwater wetlands in the Central Valley.

Talke, S. A. and M. T. Stacey (2008). "Suspended sediment fluxes at an intertidal flat: The shifting influence of wave, wind, tidal, and freshwater forcing." Continental Shelf Research 28(6): 710-725.

Using in situ, continuous, high frequency (8-16Hz) measurements of velocity, suspended sediment concentration (SSC), and salinity, we investigate the factors affecting near-bed sediment flux during and after a meteorological event (cold front) on an intertidal flat in central San Francisco Bay. Hydrodynamic forcing occurs over many frequency bands including wind wave, ocean swell, seiching (500-1000s), tidal, and infra-tidal frequencies, and varies greatly over the time scale of hours and days. Sediment fluxes occur primarily due to variations in flow and SSC at three different scales: residual (tidally averaged), tidal, and seiching. During the meteorological event, sediment fluxes are dominated by increases in tidally averaged SSC and flow. Runoff and wind-induced circulation contribute to an order of magnitude increase in tidally averaged offshore flow, while waves and seiching motions from wind forcing cause an order of magnitude increase in tidally averaged SSC. Sediment fluxes during calm periods are dominated by asymmetries in SSC over a tidal cycle. Freshwater forcing produces sharp salinity fronts which trap sediment and sweep by the sensors over short (~30min) time scales, and occur primarily during the flood. The resulting flood dominance in SSC is magnified or reversed by variations in wind forcing between the flood and ebb. Long-term records show that more than half of wind events (sustained speeds of greater than 5m/s) occur for 3h or less, suggesting that asymmetric wind forcing over a tidal cycle commonly occurs. Seiching associated with wind and its variation produces onshore sediment transport. Overall, the changing hydrodynamic and meteorological forcing influence sediment flux at both short (minutes) and long (days) time scales.

Talley, T. S., J. A. Crooks, et al. (2001). "Habitat utilization and alteration by the invasive burrowing isopod, Sphaeroma quoyanum, in California salt marshes." Marine Biology 138(3): 561-573.

In recent years the pace of exotic species introduction and invasion has accelerated, particularly in estuaries and wetlands. Species invasions may affect coastal ecosystems in many ways. Alteration of sedimentary environments, through structure formation and burrowing, has particularly dramatic effects on coastal habitats. This study examines modification of channel bank and marsh edge habitat by the burrowing Australasian isopod Sphaeroma quoyanum Milne Edwards, in created and natural salt marshes of San Diego Bay and San Francisco Bay. Abundance and distribution patterns of this isopod species, its relationships with habitat characteristics, and its effects on sediment properties and bank erosion were examined seasonally, and in several marsh microhabitats. Mean isopod densities were 1541 and 2936 individuals per 0.25 m super(2) in San Francisco Bay, and 361 and 1153 individuals per 0.25 m super(2) in San Diego Bay study sites during December and July 1998, respectively. This isopod forms dense, anastomosing burrow networks. S. quoyanum densities did not differ as a function of location within creeks or location in natural versus created marshes. Burrows, which are on average 6 mm wide and 2 cm long, were associated with firm sediments containing high detrital biomass. Although erosion is a natural process along salt marsh banks, enclosure experiments demonstrated that isopod activities can enhance sediment loss from banks. In areas infested with S. quoyanum, losses may exceed 100 cm of marsh edge per year. The effects of habitat alteration by this invading species are likely to increase in severity in the coastal zone as these ecosystems become degraded.

Tanaka, S., and M. Deas (2010). Development of RTEMP, a weekly numerical model representing unimpaired equilibrium water temperature conditions for west-slope Sierra Nevada streams and rivers. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The Sierra Nevada Mountain Range (Sierra Nevada) is expected to experience hydrologic changes under global climate change. Future conditions may include different timing, quantities, and distribution of precipitation events (rain and snow), and/or warmer air temperatures leading to earlier runoff of snowmelt from the higher elevations. To assess the possible impacts of a future climatic change on water temperatures in the major rivers of the Sierra Nevada , a regional, equilibrium based temperature model (RTEMP) was developed. RTEMP uses regionally available meteorological data and digital elevation models (DEMs) to develop weekly equilibrium water temperature (EWT) for the Mokelumne River basin in the Sierra Nevada for various stream reaches determined by elevation contours or “bands”. The model utilized a simplified version of the advection dispersion equation, the full form of the heat budget, and retains critical geometric information about the system in question. This approach produced a time series of “dynamic equilibrium temperatures,” wherein water temperature may not achieve complete equilibrium with meteorological conditions over the specified time period. The model required outputs from WEAP (including air temperature, relative humidity, precipitation, snowmelt, and surface runoff volumes, groundwater base- and inter-flows, and solar radiation) and user specified time series inputs (including cloud cover, wind speed, and initial groundwater and snowmelt temperatures), along with constants and coefficients (including emissivity, water surface reflectivity, specific heat of water, etc.), connectivity matrix, and basic basin information.

Tansey, M., F. Flores, and C. Young (2010). Modeling effects of climate change on Central Valley water demands. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Long term planning for the management of California’s water resources requires assessment of the effects of future climate changes on both water supply and demand. Considerable progress has been made on the evaluation of the effects of future climate changes on water supplies but less information is available with regard to water demands. This study addresses water demands by examining the effects of climate change on plant transpiration, growth and yield for selected types of agricultural and urban vegetation. The assessments are performed for representative groups of agricultural crops growing in characteristic geographic regions of the Central Valley using downscaled climate futures selected to span a wide range of the existing GCM results. The objective of this approach is to produce a data set that can be used by others for planning studies and economic assessments. An existing model, the Land, Air, and Water Simulator (LAWS) has been modified to include algorithms that account for effects of atmospheric temperature, radiation, humidity,

wind speed and CO2 concentrations on plant water use, growth and yield. Using LAWS, the effects of various types of agricultural and urban water demand management actions can be evaluated. Native vegetation can also be simulated. Study results show that atmospheric as well as soil conditions can exert complex and opposing influences on important evaluation metrics such as plant transpiration rates and cumulative water use, initiation and duration of the growing season, biomass production and crop yields. The magnitude of changes relative to historic conditions can be significant. Additional simulations are underway to expand the scope of the results throughout the Central Valley. These results will be directly relevant to the development of climate adaptation strategies effecting future Delta inflows.

Tasto, R. N. (1979). San Francisco Bay: critical to the Dungeness crab? San Francisco Bay: the urbanized estuary. T. J. Conomos. San Francisco, Pacific Division, American Association for the Advancement of Science: 479-490.

Teh, S. J., S. C. Acuña, et al. (2010). Effects of maternal size on larval growth and survival of delta smelt due to temperature, pesticide exposure, and starvation. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Three experiments were initiated to investigate differences in reproductive performance and survival of delta smelt (Hypomesus transpacificus) due to maternal size. The studies include: 1) larval survival produced from big and small females cultured at water temperatures of 16 degree C and 20 degree C, 2) effects of starvation on maternal size, and 3) effect of permethrin exposure on larvae spawned from big and small females. Results indicated larger females had higher fecundity, fertility, and egg hatching success than smaller females. While the size and age (0 and 5 day-post-hatch) of larvae were not affected by maternal size, the yolk/oil globular ratios decreased at a faster rate in larvae spawned from smaller relative to larger females. Survival was higher for larvae raised at 16 degree C compared to 20 degree C. All larvae were similarly affected by the toxic effects of permethrin regardless of maternal size. However, larvae spawned from smaller females had higher mortality when deprived of food for 4 days, relative to those from larger females. Overall, these findings indicate that larval survival after exposure to the pesticide was independent of maternal size, while under deprived food conditions, larvae from larger females had higher growth and survival than the larvae from smaller mothers. Such maternal effects are known to have an important influence on year-class recruitment. Because larval survival are maternally-size dependent and spawning of larger females tend to occur at the beginning of the spawning season, restoration and water conveyance measures that benefit delta smelt can be improved by targeting larger females that produce viable larvae.

Teh, S. J., D. V. Baxa, et al. (2010). Monitoring of harmful algal blooms and potential impacts to fish health in the San Francisco Estuary. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Toxic cyanobacteria such as Microcystis are a significant hazard to the environment and to human and aquatic animal health worldwide. Predicting the toxicity of algal blooms require determining the presence and abundance of toxic and nontoxic genotypes. Central to evaluating local Microcystis toxicity is monitoring environmental factors that trigger microcystin (MC) synthesis. Aquatic organisms, such as zooplankton and pelagic planktivores are directly exposed to MCs during harmful algal blooms or indirectly by ingesting MC-contaminated preys. This presentation will include an overview of several studies in our laboratory such as the potential relationships among Microcystis toxicity, trophic transfer, and pelagic fish health in the San Francisco Estuary. Some of these studies have been completed, in progress, or forthcoming and were designed to address the underlying role of Microcystis toxins as one of several stressors associated with severe decline in populations of fish and other pelagic organisms in the estuary.

Teh, S. J., I. Werner, et al. (2000). "Sublethal effects of chromium-VI in the Asian clam (Potamocorbula amurensis)." Marine environmental research 50(1-5): 295-300.
Previously, we have shown that Asian clams (Potamocorbula amurensis) with highest metallic body burdens have highest prevalence of disease and lowest

reproduction. The present study was designed to assess and validate potential sublethal toxicity of hexavalent chromium (Cr-VI) in clams under controlled laboratory exposure. For 7 days, three replicates of clam (n = 10 per replicate) were exposed to aqueous solution containing 0.00, 0.92, 8.40, or 25.6 mg 1 super(-1) of Cr-VI at 15 degree C and 15 g 1 super(-1) salinity. Mortality reached 100% in the 25.6 mg 1 super(-1) group within 7 days. There was no significant difference in mortality among the control, 0.92, and 8.40 mg 1 super(-1) groups. Western blot analyses revealed significantly elevated stress protein hsp70 levels in the 8.40 mg 1 super(-1) treatment group. Histopathologic analyses revealed mild digestive gland (DG) atrophy in the control group. Clams exposed to 0.92 mg 1 super(-1) Cr-VI showed moderate DG atrophy, moderate granulomatous inflammation and necrosis in DG, ovary and testis. Lesions observed in the 8.40 mg 1 super(-1) treatment group included severe DG atrophy, severe granulomatous inflammation and necrosis in byssal gland, DG, gill, kidney, ovary and testis. In gills and testes of treated groups, apoptotic cells outnumbered mitotic cells. In addition, gills from clams in the 8.40 mg 1 super(-1) group showed enhanced hsp 70 staining. Our studies support a cause-effect relationship between contaminants and reduced health in Asian clams and indicate the DGs, gill, and reproductive organs are principal targets of Cr-VI toxicity at sublethal concentrations. Results from this study suggest that Cr-VI may have played a role in the increased incidence of diseased clams seen in previous studies and these adverse effects may be working to decrease clam populations at sites with highest metallic contamination in the San Francisco Bay Estuary.

Teh, S. J., G. H. Zhang, et al. (2004). Lethal and Sublethal Effects of Esfenvalerate and Diazinon on Splittail Larvae. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 243-253.
Runoff from dormant spray applications to orchards can contain the insecticides diazinon and esfenvalerate, which may affect the health of the threatened splittail Pogonichthys macrolepidotus. To examine the potential effects of these two insecticides, splittail larvae were exposed to diazinon, esfenvalerate, and a mixture of the two insecticides in static renewal 96-h acute toxicity tests. Surviving fish were transferred to clean water for an additional 14 d (18 d total). Mortality, morphological anomalies, histopathology, and growth determinations were made to assess lethal and sublethal effects. The combination of diazinon and esfenvalerate produced less than additive (independent) toxicity. Diazinon (singly and in combination with esfenvalerate) produced latent toxicity after the 96-h exposure, as demonstrated by reduced growth and increased spinal deformities. Metabolic dysfunction in the liver and inflammation of the pancreas were likely related to slower growth of diazinon-exposed fish. These symptoms were almost absent from esfenvalerate-exposed fish. The use of 14-d EC50 values and the measurement of biomarkers may more accurately describe the effects of 96-h short-term exposure to these insecticides than traditional 96-h LC50 values.

Templin, W. E., D.B. Green, and R.F. Ferriera (1980). Water-quality data from Taylor Creek drainage basin, El Dorado County, California, July 1975 through October 1976. Open-File Report 80-1178. Sacramento, CA, U.S. Geological Survey: 95.
Data were collected from July 1975 through October 1976 to establish benchmark water-quality conditions in the Taylor Creek drainage basin in California. The Taylor Creek drainage basin is a high-altitude system of lakes and streams which forms one of the tributaries to Lake Tahoe in the Sierra Nevada of California and Nevada. Sampling sites were distributed between the upper and lower reaches of the basin. Streamflow and water-quality data were collected at 13 stream sites. Water-quality data and depth profiles were collected at six lake sites. The reconnaissance included measurement and evaluation of the following selected characteristics: major chemicals, nutrients, fecal coliform bacteria, phytoplankton, periphytic algae, benthic macroinvertebrates, primary productivity, and stream community diversity.

Templin, W. E. (1982). Achieving more efficient water data collection with systems analysis. Business and Public Administration. Sacramento, California State University, Sacramento. Masters of Public Administration: 35.

Templin, W. E. (1984). Ground-water Quality Monitoring Network Design for the San Joaquin Valley, California. Water Resources Investigations Report 83-4080. Sacramento, CA, U.S. Geological Survey: 133, plus 118 maps.
Ideal and actual ground-water-quality monitoring networks are proposed for the San Joaquin Valley basin in California. The ideal network, which comprised several subnetworks, provides direction in the development of an actual network of wells currently monitored by known operating agencies. The ideal network can serve as a basis for the future expansion of the actual network as more wells are included in the inventory of active monitoring networks. The management objectivs of these networks are to develop an general baseline of ground-water quality and to identify large-scale sources of contamination for ground water. The networks are based on an information structure that includes land use, surface and subsurface geology, ground-water levels, surface and ground water quality, possible sources of contamination, and active ground water quality monitoring networks. Development of the categories and subcategories of network objectives, which are needed to describe the quality of the ground water in the basin, makes clear the inadequacy of the currently operated networks. The expansion of the ground-water-quality monitoring in the San Joaquin Valley, therefore, would be necessary to approximate the ideal network.

Templin, W. E. (1985). Regional Ground-Water Quality Network Design. Groundwater Contamination and Reclamation Symposium. K. D. Schmidt. Tucson, AZ, American Water Resources Association: 37-44.
This paper describes the approach used in designing a regional network to monitor the complex ground-water-quality conditions in the San Joaquin Valley, California. The actual network approximates the ideal network with the constraint of primarily using wells that are already being monitored by someone for some purpose. Further inventories of monitoring networks and installation of some specialized monitoring wells will be needed. Use of statistical network analysis techniques is also needed to make network improvements. Following these actions, the actual network will more closely approximate the ideal network in providing information on ground-water-quality trends, contaminant sources, prevention of future sources of contamination, monitoring well distributions, sampling frequencies, and constituents to be monitored.

Templin, W. E. (1986). Water-Use Information for California. Open-File Report. Sacramento, CA, U.S. Geological Survey. Open-File Report 86-483: 8.
This pamphlet reports on the availability of water use information to and for the state of California, through the development of the State Water-Use Data System (SWUDS). SWUDS is currently organized into 12 water use categories: Agricultural non-irrigation; Commercial; Domestic; Industrial; Irrigation; Mining; Power generation--fossil fuel, geothermal, hydroelectric , nuclear; Sewage treatment; and Water supply. The information needs of this system include type of water use (by category); name of water user; location of water use (latitude/longitude, county, and hydrologic unit--drainage basin); sources of water supply and return (fresh, saline, or reclaimed surface or groundwater); volume of water withdrawn, delivered, consumed, released, and returned; and period of water use (month, year).

In 1977, the Congress of the United States recognized the need for uniform information on water use and directed the U.S. Geological Survey to establish a National Water-Use Information Program to complement the Survey's data on the availability and quality of the Nation's water resources. The Geological Survey started a water-use information program in 1978 to provide for the comprehensive and systematic collection, storage, analysis and dissemination of water-use data and information throughout the United States. Statistics on agricultural, domestic, and industrial water use are required for the planning, management, and development of the Nation's and California's water resources. Thes statistics are also needed to provide information necessary to identify and resolve critical water problems relating to environmental impacts, resource allocations, water quality, and energy development. The U.S. Geological Survey is addressing this need by collecting and publilshing information on major water uses within the State.

Templin, W. E. (1988). The California Water-Use Geographic Information System. Water-Use Data For Water Resources Management, Tucson, AZ, American Water Resources Association, 5410 Grosvenor Lane, Suite 220, Bethesda, Maryland, 20814-2192 301-493-8600.
This paper describes the organization and some of the capabilities of the geographic information system now being refined and used in the U.S. Geological Survey office in Sacramento, California. Geographic information system techniques are being used to developp, analyze, and integrate water-use and related information. Objectives of the U.S. Gelogical Survey's State Water-Use Information Programs address the need for both statewide and site-specific information on water use in 12 nationally determined categories. In California, the state with the largest water use in the Nation, the large volume of water used and the large number of users, present major problems in meeting these objectives.

Templin, W. E. (1990). California Water Supply and Use. Water Supply Paper 2350. J. E. Carr, E.B. Chase, R.W. Paulson, and D.W. Moody. Denver, CO, U.S. Geological Survey: 173-182.
California, which has the largest volumn of offstream water use in the Nation, consistently leads all States in surface- and ground-water withdrawals. The State has retained this position for 40 years, primarily because of the large volumen of irrigated agriculture. Califonia's water budget shows that available water supplies originate from precipitation, ground-water storage depletion, and surface-water inflow from adjacent states. A complex water-management system has developed in response to a geographic and seasonal mismatch between supply and demand. In 1985, 37, 400 Mgal/d of freshwater was withdrawn from streams and aquifers - equivalent to almost 1, 420 gal/d per capita. Of this water, 56.4 percent was consumed, and the balance was returned to surface and ground water. Agriculture accounted for 82.4 percent of the total freshwater withdrawals in 1985; of this amount, 66.2 percent was surface water, and 33.8 percent was ground water. Although consumptive use cannot be quantified precisely using available information, irrigation probably accounted for about 90 percent of the consumptive use of freshwater in 1985. Californians are concerned about many major water use issues; one of the most notable is the recurrent proposal to increase delivery of water from the north to the south and the resultant effects such action would have on water supplies and quality in northern counties. A second major issue is the use of irrigation water and return flows on the western side of the San Joaquin and Tulare-Buena Vista Lakes basins.

Templin, W. E., T.C. Haltom, and D.E. Cherry (1993). Water Supply and Demand in the Antelope Valley, California. Effluent Use Management, Tucson, AZ, American Water Resources Association.

Templin, W. E., and T.C. Haltom (1994). Irrigation water supply and demand data for 1976, 1980 and 1984 for the Western San Joaquin Valley, CA. Open-File Report. Sacramento, CA, U.S. Geological Survey. 94-335: 8 plus data disc.
This report presents the irrigation water supply and demand data for 1976, 1980, and 1984 for 32 water districts in the western San Joaquin Valley, California. Data are provided for each water district or each of the three years if the data were available. The complete data base is given by water district or each township, range, and section in the rectangular system for the subdivision of public lands. These data were complied for use in a ground- water-flow model, compilation of a water-budget, and use by the San Joaquin Valley Drainage Program in a study of water management in the western San Joaquin Valley, California. The data are presented in a computer-readable format to improve data utilization and to condense the information so that it can be more readily distributed to users.

Templin, W. E., S.P. Phillips,., D.E. Cherry., M.L DeBortoli, T.C. Haltom.,K.R. McPherson,. and C.A. Mrozek (1995). Land use and water use in the Antelope Valley, California. Water-Resources Investigations Report: 97.
Urban land use and water use in the Antelope Valley, California, have increased greatly since the development of the valley began in the late 1800's. Ground water always has been a major source of supply in this area because of limited local surface-water resources. Ground-water pumpage reportedly increased

from about 29,000 acre-feet in 1919 to about 400,000 acre-feet in the 1950's. Declines in ground-water levels and increased costs of electrical power in the 1970's resulted in a reduction in the quantity of ground-water pumped annually for irrigation uses. Ground-water pumpage was further reduced in the 1970's following the completion of the California Aqueduct, which conveys water from northern California. Total annual reported ground-water pumpage decreased to a low of about 53,200 acre-feet in 1983 and increased again to about 91,700 acre-feet in 1991. Rapid urban development and the 1987-92 drought renewed concern about a possible return to extensive ground-water- storage depletion and increased land subsidence. Water-demand forecasts in 1980 for the Antelope Valley indicated that total annual demand by the year 2020 was expected to be about 250,000 acre- feet per year, with agricultural uses to be about 65 percent of this total demand. In 1990, total demand. In 1993, preliminary forecasts for total demand for 2010 ranged from about 127,000 to 329,000 acre-feet with urban water uses accounting for all but a few percent of the total anticipated demand. This history of forecasts indicates that expectations change with time. Factors that affect water demand change and different forecasting methods are used. Water-conservation options may be adopted to employ best-management practices that would further influence future water demands in the Antelope Valley.

Templin, W. E., P.E. Smith, M.L. DeBortoli, and R.C. Schluter (1996). Water-resources data-network evaluation for Monterey County, CA: Phase 2, northern and coastal areas of Monterry County. Water-Resources Investigations Report. Sacramento, CA, U.S. Geological Survey.
This report presents an evaluation of water-resources data-collection networks in the northern and coastal areas of Monterey County, California. This evaluation was done by the U.S. Geological Survey in cooperation with the Monterey County Flood Control and Water Conservation District to evaluate precipitation, surface water, and ground water monitoring networks. This report describes existing monitoring networks in the study areas and areas where possible additional data-collection is needed. During this study, 106 precipitation-quantity gages were identified, of which 84 were active; however, no precipitation-quality gages were identified in the study areas. The precipitaion-quantity gages were concentrated in the Monterey Peninsula and the northern part of the county. If the number of gages in these areas were reduced, coverage would still be adequate to meet most objectives; however, additional gages could improve coverage in the Tularcitos Creek basin and in the coastal areas south of Carmel to the county boundary. If collection of precipitation data were expanded to include monitoring precipitation quality, this expanded monitoring also could include monitoring precipitation for acid rain and pesticides. Eleven continuous streamflow-gaging stations were identified during this study, of which seven were active. To meet the objectives of the streamflow networks outlined in this report, the seven active stations would need to be continued, four stations would need to be reactivated, and an additional six streamflow-gaging stations would need to be added. Eleven stations that routinely were sampled for chemical constituents were identified in the study areas. Surface water in the lower Big Sur River basin was sampled annually for total coli- form and fecal coliform bacteria, and the Big Sur River was sampled monthly at 16 stations for these bacteria. Routine sampling for chemical constituents also was done in the Big Sur River basin. The Monterey County Flood Control and Water Conservation District maintained three networks in the study areas to measure ground-water levels: (1) the summer network, (2) the monthly network, and (3) the annual autumn network. The California American Water Company also did some ground-water-level monitoring in these areas. Well coverage for ground-water monitoring was dense in the seawater-intrusion area north of Moss Landing (possibly because of multiple overlying aquifers), but sparse in other parts of the study areas. During the study, 44 sections were identified as not monitored for ground-water levels. In an ideal ground-water-level network, wells would be evenly spaced, except where local conditions or correlations of wells make monitoring unnecessary. A total of 384 wells that monitor ground-water levels and/or ground-water quality were identified during this study. The Monterey County Flood Control and Water Conservation District sampled ground-water quality monthly during the irrigation season to monitor seawater intrusion. Once each year (during the summer), the wells in this network were monitored for chlorides, specific conductance, and nitrates. Additional samples

were collected from each well once every 5 years for complete mineral analysis. The California Department of Health Services, the California American Water Company, the U.S. Army Health Service at Ford Ord, and the Monterey Peninsula Water Management District also monitored ground-water quality in wells in the study areas. Well coverage for the ground-water- quality networks was dense in the seawater- intrusion area north of Moss Landing, but sparse in the rest of the study areas. During this study, 54 sections were identified as not monitored for water quality.

Templin, W. E., and D.E. Cherry (1997). Drainage-return, surface-water withdrawal, and land-use data for the Sacramento-San Joaquin Delta, with emphasis on Twitchell Island, California. Open-File Report. Sacramento, CA, U.S. Geological Survey: 31 pp.
Partial data on drainage returns and surface-water withdrawals are presented for areas of the Sacramento-San Joaquin Delta, California, for March 1994 through February 1996. These areas cover most of the delta. Data are also presented for all drainage returns and some surface-water withdrawals for Twitchell Island, which is in the western part of the delta. Changes in land use between 1968 and 1991 are also presented for the delta.

Templin, W. E. (1998). California - Continually the Nation's Leader in Water Use. American Water Resources Association Annual Conference on Water Resources, November 16-19 1998. Point Clear, Alabama.
In 1950, the U.S. Geological Survey began publishing a series of water-use circulars entitled "Estimated Use of Water in the United States." Every 5 years since then the report has been updated and now provides a valuable, long-term data set of national water-use estimates. Since the inception of this series, California has always reported the largest total fresh and saline withdrawals of all states in the Nation (fig. 1). The most recent update in this series (Solley and others, 1998) reports 1995 conditions. California again accounts for the largest withdrawal of water for off-stream uses of all states, which is about 45.9 billion gallons per day, followed by Texas (29.6 Bgal/d), Illinois (19.9 Bgal/d), and Florida (18.2 Bgal/d, figs. 2 and 3).

Templin, W. E., R.A. Herbert, C.B. Stalnaker, M. Horn, and W.B. Solley (1999). Water Use Chapter 11 of National Handbook of Recommended Methods for Water Data Acquisition. National Handbook of Recommended Methods for Water Data Acquisition, U.S. Geological Survey. Chapter 11.
The increased demand for water and the increased concern for the quality of the water resources of the United States logically has led to an increased demand for water-resources data, including water-use data. The need for more detailed and accurate data on both ground-water and surface-water use becomes critical as demand for water resources increases and supplies become more limited because of drought, ground-water depletion, or deteriorating water quality. In addition, many recent court and compact decisions have recognized the importance of instream flows and often have mandated an increase in instream flows to meet various recreational and environmental needs, thus increasing the demand on the water resource.

The purpose of Chapter 11 of the National Handbook of Recommended Methods for Water Data Acquisition is to provide standards and guidance in measuring, estimating, collecting, compiling, and analyzing water-use data. This chapter includes a brief description of (1) water-use activities and commonly used water-use terminology, (2) approaches and methods used in measuring and estimating water use, (3) water-use-data-management systems, and (4) methods for determining water use for specific water-use categories. Where appropriate, descriptions include accuracy, quality assurance procedures, and water-use data collection instrumentation. Methods of measuring and estimating water use vary widely. The use of recommended methods, estimation techniques, terminology, and definitions for water-use data acquisition help ensure that the water-use estimates will meet certain requirements for content and uniformity for a wide variety of purposes.

Templin, W. E., American River Watershed Coordinator (2007). North Fork/Middle Fork American River Sediment Study: 172.
The North Fork/Middle Fork American River Sediment Study uses a coarse-filtered, geographic information system (GIS)-based, subwatershed relative

potential risk screening model for soil erosion and sedimentation. It synthesizes relevant information using a map-based approach to support decision-making, and provides a spatial model that prioritizes the relative risk of erosion and sedimentation
by subwatershed, regardless of land ownership. Watershed indicators are used to characterize potential erosion and sedimentation hazards. The knowledge-based modeling and risk- based prioritization achieves a consistent treatment of the individual subwatersheds that make up the watershed assessment area. The outcomes of the watershed modeling and prioritization process are used to prioritize and target management strategies (i.e., best management practices,
disturbance minimization, and active restoration) for higher potential risk areas (relative to erosion and sedimentation under bare soil conditions) to enhance or maintain watershed health by minimizing potential sediment-related impacts to key resources. The prioritization can also be used as a framework for the development and implementation of a watershed monitoring plan. The opportunities for watershed protection and restoration, with emphasis in priority category 1 and 2 subwatersheds (7th-level hydrologic unit code [HUC]), are voluntary in nature with no intended land owner mandates or land-use related regulations. For successful implementation of the management strategies and priorities, a coordinated and collaborative process (including education and outreach for information sharing) among stakeholders is needed. With existing gaps in knowledge or data, an adaptive resource management approach (using inventory, monitoring, research, and adjustment) is essential for the implementation of the subwatershed-based management strategies.

Templin, W. E., V. Conner, K. Gehrts, A. Osti, D. Osti, and A. Webber-Stover (2012). California Estuary Monitoring Workgroup Website - a Tool for integrating Monitoring Assessment and Reporting. 7th Bienniel Bay-Delta Science Conference: October 16-18, 2012, Sacramento Convention Center, 1400 J St. Sacramento, CA.

http://scienceconf.deltacouncil.ca.gov/sites/default/files/documents/abstracts/poster/A5MonitoringWebPortalsBDSC2012.pdf
The California Estuaries Monitoring Workgroup (CEMW) has formed under the guidance of the
California Water Quality Monitoring Council (Monitoring Council). The group is focusing on the
San Francisco Bay Delta Estuary, but will be expanded to other estuaries as statewide input is
received. The goal of the CEMW is to evaluate existing estuarine resource monitoring,
assessment and reporting efforts and work to enhance those efforts to improve the delivery of
water quality and ecosystem health information to the user, in the form of the California
Estuaries Portal (Portal). The CEMW will follow the Monitoring Council's guidance as it
develops a Portal that delivers intuitive, streamlined access to estuary ecosystem health
information that directly addresses users' questions. The CEMW will review technical and
policy aspects of estuarine resource monitoring, tool development, implementation and use of
data to improve estuarine resource management.
The San Francisco Bay Delta is the state's largest and most important estuary. Many state,
federal and local agencies, universities, regulated dischargers, public water agencies, and water
bond grant recipients spend millions of dollars each year monitoring, assessing and reporting
on the conditions of the San Francisco Bay-Delta Estuary ecosystem. It is hoped that the CEP
can assist with the integration of Bay Delta Monitoring and Science.

Templin, W. E. a. R. C. S. (1990). A Water-Resources Data-Network Evaluation for Monterey County California - Phase 3: Northern Salinas River Drainage Basin. Water-Resources Investigations Report 89-4123. Sacramento, CA, U.S. Geological Survey: 96.

This report evaluates existing data collection networks and possible additional data collection to monitor quantity and quality of precipitation, surface water, and groundwater in the northern Salinas River drainage basin, California. Of the 34 precipitation stations identified, 20 were active and are concentrated in the northwestern part of the study area. No precipitation quality networks were identified, but possible data collection efforts include monitoring for acid rain and pesticides. Six of ten stream-gaging stations are active. Two surface water quality sites are sampled for suspended sediment, specific conductance, and chloride; one U.S. Geological Survey NASOAN site and one site operated by California Department of Water Resources make up the four active sampling locations; reactivation of 45 inactive surface water quality sites might help to achieve objectives described in the report. Three local networks measure water levels in 318 wells monthly, during peak irrigation, and at the end of the irrigation season. Water quality conditions are monitored in 379 wells; samples are collected in summer to monitor saltwater intrusion near Castroville and are also collected annually throughout the study area for analysis of chloride, specific conductance, and nitrate. An ideal baseline network would be an evenly spaced grid of index wells with a density of one per section. When baseline conditions are established, representative wells within the network could be monitored periodically according to specific data needs. (USGS)

Thayer, G. W., D. R. Colby, et al. (1983). "ESTIMATES OF LARVAL-FISH ABUNDANCE - DIURNAL-VARIATION AND INFLUENCES OF SAMPLING GEAR AND TOWING SPEED." Transactions of the American Fisheries Society 112(2): 272-279.

Thebault, J., T.S Schraga, J.E. Cloern, and E.G. Dunlavy (2008). "Primary production and carrying capacity of former salt ponds after reconnection to the San Francisco Bay." Wetlands 28(3): 11.

Thomas, J. L. (1967). "The diet of juvenile and adult striped bass, Roccus saxatilis, in the Sacramento-San Joaquin River system." California Fish and Game 53: 49-62.

Thomas, M., and A.P. Klimley (2010). Fine scale movements of adult green sturgeon in the Sacramento River. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

The green sturgeon, Acipenser medirostris, is one of two acipenserid fishes native to the Central Valley. We describe the fine scale movements, behavior, and habitat preference of five adult green sturgeon during periods of spawning activity. Sexually mature adult green sturgeon were captured by gill net in the upper reaches of the Sacramento River near Red Bluff California, over a three year period between 2008 and 2010. Two ultrasonic tags, one transmitting the identity of the individual and the other sensing its depth and surrounding water temperature, were surgically implanted within the peritoneal cavity of ten green sturgeon. Individuals were then relocated and tracked by boat using an ultrasonic receiver and directional hydrophone fitted with an internal GPS. The fish were tracked continuously twenty four hours per day for up to five days. Recordings of GPS coordinates, depth, and water temperature at the sturgeon’s location and environmental conditions such as pH, dissolved oxygen, turbidity, and water temperature were recorded from the tracking vessel using a multi probe, configured with a depth sounder and GPS. The green sturgeon exhibited periods of sustained holding in one place and sustained directional movements between known spawning aggregate sites. In addition to known spawning aggregate locations, two new sites were identified as potential locations for monitoring spawning activity through placement of egg mats and larval traps by fisheries biologists of USFWS, Red Bluff. Contrary to the current belief that green sturgeon remain stationary within pools within the river, individuals were found to be highly mobile and exhibit sustained movements over great distances between aggregate locations both above and below Red Bluff Diversion Dam (RBDD). We have

described such oscilating movements as “ping-pong” behavior. These may be of critical importance because they may enable an individual of one sex to locate individuals of the opposite sex. Our results emphasize the importance of permitting individuals to freely mix within the entirety of their spawning range. It is our opinion that the recent decision to discontinue the operation of the RBDD gates, which block upstream movements by green sturgeon, will be beneficial to the southern distinct population segment of green sturgeon populations.

Thompson, B., B. Anderson, J. Hunt, K. Taberski, and B. Phillips (1999). "Relationships between sediment contamination and toxicity in San Francisco Bay." Marine Environmental Research 48(4-5): 285-309.

Sediment contamination and toxicity were monitored at 14 sites in San Francisco Bay between 1991 and 1996. Sediment contamination patterns were different in the major reaches of the Bay, and at each site. Several contaminants were consistently above concentrations previously associated with toxicity at most sites. Bulk sediment bioassays using the amphipod Eohaustorius estuarius and sediment elutriate bioassays using larval bivalves (Mytilus spp., Crassostrea gigas) also indicated different patterns of sediment toxicity in space and time. Sediments were most toxic to the amphipods at Redwood Creek (90% of the tests), and were toxic in at least half the tests conducted at five other sites. Sediment elutriates severely reduced normal bivalve larval development at the San Joaquin and Sacramento Rivers in all samples, but toxicity occurred in less than a third of the tests in the Central and South Bays. Toxicity could not be statistically related to seasonal freshwater flow or rainfall in the Bay, but seasonal variation in contaminant concentrations and toxicity was observed. Amphipod toxicity was inversely and significantly related to the mean effects range-median quotient, suggesting that cumulative concentrations of several contaminants were related to toxicity. Further analysis identified suites of specific contaminants at each site that were variably related to amphipod toxicity at each site. Chlordanes, cadmium, and silver were significantly related to amphipod survival in the North Bay. Seasonal patterns in low, and high molecular weight polycyclic aromatic hydrocarbons (PAHs) were related to toxicity at Alameda, and metals and PAHs were related to toxicity at Castro Cove. Larval bivalve toxicity was associated with metals in bulk sediments, but elutriate chemistry was not measured, and relationships with toxicity could not be examined. Hypotheses about effective concentrations of several individual contaminants and mixtures of contaminants were posed.

Thompson, B., T. Adelsbach, et al. (2007). "Biological effects of anthropogenic contaminants in the San Francisco Estuary." Environmental Research 105(1): 156-174.

Concentrations of many anthropogenic contaminants in the San Francisco Estuary exist at levels that have been associated with biological effects elsewhere, so there is a potential for them to cause biological effects in the Estuary. The purpose of this paper is to summarize information about biological effects on the Estuary's plankton, benthos, fish, birds, and mammals, gathered since the early 1990s, focusing on key accomplishments. These studies have been conducted at all levels of biological organization (sub-cellular through communities), but have included only a small fraction of the organisms and contaminants of concern in the region. The studies summarized provide a body of evidence that some contaminants are causing biological impacts in some biological resources in the Estuary. However, no general patterns of effects were apparent in space and time, and no single contaminant was consistently related to effects among the biota considered. These conclusions reflect the difficulty in demonstrating biological effects due specifically to contamination because there is a wide range of sensitivity to contaminants among the Estuary's many organisms. Additionally, the spatial and temporal distribution of contamination in the Estuary is highly variable, and levels of contamination covary with other environmental factors, such as freshwater inflow or sediment-type. Federal and State regulatory agencies desire to develop biological criteria to protect the Estuary's biological resources. Future studies of biological effects in San Francisco Estuary should focus on the development of meaningful indicators of biological effects, and on key organism and contaminants of concern in long-term, multifaceted studies that include laboratory and field experiments to determine cause and effect to adequately inform management and regulatory decisions.

Thompson, B., R. Hoenicke, et al. (2000). "An overview of contaminant-related issues identified by monitoring in San Francisco Bay." Environmental Monitoring and Assessment 64(1): 409-419.

The San Francisco Estuary Regional Monitoring Program for Trace Substances (RMP) began in 1993 and is sponsored by 74 local, state, and federal agencies and companies through their discharge or Bay use permits. The RMP monitors water, sediment, toxicity, and bivalve bioaccumulation at 25 sites in the Bay that are considered to represent "background" conditions. Several major environmental issues have been identified by the RMP. Polychlorinated biphenyls and mercury were often above water quality guidelines, and often occurred in fish tissues above U.S. Environmental Protection Agency (U.S. EPA) screening values. Concentrations do not appear to be decreasing, suggesting continuing inputs. Episodes of aquatic toxicity often occurred following runoff events that transport contaminants into the Bay from urbanized and agricultural portions of the watershed. Sediment toxicity occurred throughout the Bay, and has been correlated with concentrations of specific contaminants (chlordanes, polynuclear aromatic hydrocarbons) at some locations; mixtures of contaminants were probably also important. Since the RMP does not monitor all ecosystem components, assessments of the overall condition of the Bay cannot be made. However, in terms of contamination, the RMP samples suggest that the South Bay, and North Bay sites are moderately contaminated.

Thompson, B. and S. Lowe (2004). "Assessment of macrobenthos response to sediment contamination in the San Francisco Estuary, California, USA." Environmental Toxicology and Chemistry 23(9): 2178-2187.

A multimetric benthic assessment method was developed for two benthic assemblages in the San Francisco Estuary (USA) using data from several monitoring programs collected over five years. Assessment indicators used were total number of taxa, total abundances, oligochaete abundances, number of molluscan taxa, number of amphipod taxa, and Capitella capitata and Streblospio benedicti abundances. Exceedances of the maximum or minimum indicator values in reference samples were used to assess test samples using a weight-of-evidence to obtain an assessment value. Only 2.5% of the samples from the deeper, offshore sites had benthic impacts, 14.3% of the samples from near wastewater discharges had impacts, and 78.3% of the samples from the estuary margins and channels were impacted. Impacted samples from both assemblages had significantly higher mean effects range-median quotient values (mERMq) than reference samples, total organic carbon (TOC) was significantly higher in the impacted samples from the mesohaline assemblage, and percent fines was significantly higher in the impacted samples from the polyhaline assemblage, reflecting the close associations of contaminants with fine sediments and organic material. In samples with mERMq below 0.050, there were no benthic impacts. The incidence of impacts remained low (9.4%) at mERMq below 0.146, but when mERMq was above 0.146, 68.2% of the samples had benthic impacts, and samples with mERMq above 0.740 were always impacted.

Thompson, J., K. Hieb, L.R. Brown, F. Parchaso, and K. Gehrts (2010). Clams, fish, shrimp, birds, and phytoplankton: Causes and effects of seasonal and interannual variability in clam biomass and grazing in the northern San Francisco Estuary. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Bivalves in the San Francisco Estuary are important as (1) prey for birds, demersal fish and invertebrates; (2) consumers of phytoplankton, microzooplankton, bacteria, and zooplankton; and (3) as vectors of contaminants. These multiple bivalve connections to the ecosystem mean it is important to understand what drives the seasonal and inter-annual variability in bivalve abundance and biomass in the estuary. We have used bay-specific conceptual models of bivalve recruitment, growth and mortality to understand and demonstrate the two major time scales of variability. Time series of bivalve biomass and abundance data were examined in conjunction with time series of environmental data and abundance of bivalve predators to determine the primary causes of the bivalve fluctuations. Seasonal variability in most of the northern estuary can be accounted for by a combination of physiological stresses due to long duration low salinity periods, natural mortality due to old age, and predation by birds. Interannual variability is driven by extremely high freshwater flow events and interannual variability of specific

predators in the different embayments of the estuary. The San Francisco Bay Study (CDFG) trawl time series has allowed us to examine the close timing between bivalve recruitment, high demersal fish, shrimp and crab abundance, and the subsequent demise of the bivalve population in San Pablo Bay during good recruitment years of those predators. The result of this variability is that bivalve grazing in the years of high predation is very low thereby reducing grazing pressure on the phytoplankton during the summer and fall periods. We hypothesize that when large populations of demersal fish and invertebrates preyed on smaller juvenile clams, the adult bivalves that are prey for migrating ducks have greatly declined. Suisun Bay bivalve populations have fluctuated interannually but there is less evidence of changes in predator abundance driving the variability in this embayment.

Thompson, J. (2010). Invasive species risk assessment and planning – a tool to reduce the risk of spreading invasive species in natural resource management activities. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
        Invasive species are a known threat to species diversity, water movement, infrastructure maintenance, and human health. A regional overview of invasive species, potential pathways for moving invasive species and the process that can reduce this risk will be introduced as part of an overview of the US Fish and Wildlife Service's new Invasive Species and Risk Assessment and Planning tool or ISRAP. The ISRAP tool is a science-based approach for limiting the unintentional spread of invasive species. Natural resource management activities such as animal and plant surveys and movements, restoration construction, environmental monitoring and others can provide a pathway for the spread invasive species. These non-targets species, both plants and animals, can be transferred on clothing, sampling equipment, vehicles, or gear during these activities. ISRAP provides a solution by assessing the risk of an activity for moving invasive species from one location to another and identifying methods or procedures that can be used to reduce this risk of spread. ISRAP is an updated version of Hazard Analysis and Critical Control Point or HACCP planning.

Thompson, J. G., M. Parker, W. Templin, and R.R. Reynolds, Jr. (1993). "A Review of Application Issues of the Metropolitan Water District-Main Water Forecasting System." Water Resources Bulletin 29(3): 9.
        This paper reviews the processes that occurred during an application of the Metropolitan Water District, (MWD) -MAIN water use forecasting system for the City of Salinas, California. The review includes an analysis of sources of available data, methods for estimating input data, calibration, and verification of the MWD-MAIN System, and an evaluation of the reliability of system output. We found that inexperienced users can have difficulty understanding the level of skill, knowledge, an amount of data that are required to product reliable forecasts. Reviews such as this can help users to appreciate the level of data required, and to use the MWD-MAIN System in a more effective and efficient manner.

Thompson, J. K. (1982). "Population structure of Gemma gemma (Bivalvia: Veneridae) in South San Francisco Bay, with a comparison to some northeastern United States estuarine populations." The Veliger 24: 281-290.

Thompson, J. K. (2000). Two stories of phytoplankton control by bivalves in San Francisco Bay: The importance of spatial and temporal distribution of bivalves. Journal of Shellfish Research, Seattle.
        The introduction of the Asian clam, Potamocorbula amurensis, into San Francisco Bay has resulted in changes to the food web within the northern bay (NB) but not within the southern bay (SB). P. amurensis invaded the bay in 1986, became the dominant member of the benthic community within one year in NB and within three years in SB. Large declines in phytoplankton biomass in NB appear to be due to "over-grazing" by P. amurensis populations which are estimated to filter the shallow reaches of NB in excess of twice a day. Because high turbidity restricts net positive primary production to the shallow reaches of NB and limits the net primary production in the deep areas of SB, shallow water grazing controls system-wide phytoplankton biomass throughout the system. SB phytoplankton biomass has not changed with the invasion of P. amurensi, despite similar density and biomass levels

of P. amurensis in the deep water throughout the system. There are, however, large differences in the temporal and spatial distribution of shallow water P. amurensis in the NB and SB. Shallow water P. amurensis live 1 one half -2 years in the NB but only 8-9 months in the SB, and the annual phytoplankton bloom in SB occurs during the three month period when P. amurensis are absent from the shallow water.

Thompson, J. K. (2005). One estuary, one invasion, two responses: Phytoplankton and benthic community dynamics determine the effect of an estuarine invasive suspension-feeder. Comparative Roles of Suspension-Feeders in Ecosystems: 291-316.
Invasive suspension-feeding bivalves have reduced phytoplankton biomass in many aquatic systems, which has resulted in loss of trophic complexity in some systems. Using an example of one invasive bivalve in San Francisco Bay, Potamocorbula amurensis, the causes of differing system level responses are explored. San Francisco Bay, similar to of other shallow, turbid, non-nutrient limited, but low productivity systems, is likely to be most stressed by the loss of primary producers. While the northern bay has lost primary production following the invasion of P. amurensis, the southern bay (SB) has not and these differences are shown to be due to the different mechanisms responsible for the seasonal turbidity in the systems. Because the period of lowest turbidity in SB is coincident with the period of lowest bivalve grazing, the southern bay has not seen a reduction in its high magnitude but short spring bloom. A method for predicting if a shallow, turbid and nutrient replete estuary might lose phytoplankton production with a sudden increase in suspension-feeders is explored.

Thompson, J. K., J. R. Koseff, et al. (2008). "Shallow water processes govern system-wide phytoplankton bloom dynamics: A field study." Journal of Marine Systems 74(1-2): 153-166.
Prior studies of the phytoplankton dynamics in South San Francisco Bay, California, USA have hypothesized that bivalve filter-feeders are responsible for the limited phytoplankton blooms in the system. This study was designed to examine the effects of benthic grazing and light attenuation on this shallow, turbid, and nutrient replete system. We found that grazing by shallow water bivalves was important in determining phytoplankton bloom occurrence throughout the system and that above a shallow water bivalve grazing threshold, phytoplankton biomass did not exceed bloom levels. Wind speed, used as a proxy for light attenuation in the shallow water, was similarly important in determining bloom development in the shallow water. Environmental conditions and benthic grazing in the deep water channel had a less discernible effect on system-wide phytoplankton blooms although persistent water column stratification did increase bloom magnitude. The shallow water bivalves, believed to be preyed upon by birds and fish that migrate through the system in fall and winter, disappear each year prior to the spring phytoplankton bloom. Because growth of the phytoplankton depends so strongly on shallow water processes, any change in the shallow-water benthic filter-feeders or their predators has great potential to change the phytoplankton bloom dynamics in this system. (C) 2007 Elsevier B.V. All rights reserved.

Thompson, J. K. and F. H. Nichols (1988). "Food availability controls seasonal cycle of growth in Macoma balthica (L.) in San Francisco Bay, California." Journal of Experimental Marine Biology and Ecology 116: 43-61.
A 2-yr field study of growth in the bivalve Macoma balthica at four locations in San Francisco Bay, California, U.S., showed that the timing and rate of growth (increase in shell length) were related to food supply. This clam feeds on both planktonic and benthic microalgae, depending on availability. Growth was apparently food-limited during some months, during one year more than the other, and at some locations more than others.

Thompson, L., C. Mosser, and P. Moyle (2010). Climate change and spring-run Chinook salmon in California: Predictions of salmon responses in Butte Creek, CA from coupled watershed and population dynamics models. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Spring-run Chinook salmon (Oncorhynchus tshawytscha) are particularly vulnerable to climate change because adults hold in freshwater for the summer before

spawning in autumn. Our objective was to determine the streamflow and temperature thresholds that lead to long-term losses or reductions in spring-run Chinook salmon in a California stream, and to evaluate management options to ameliorate these impacts. Our main hypothesis was that climate-induced changes in flow and temperature will lead to critical reductions in the available habitat of spring-run Chinook salmon. We used WEAP21, an integrated watershed hydrology, water and irrigation management, and water quality model to simulate potential changes in flow and temperature in response to climate change for Butte Creek, California. WEAP21 outputs were used to drive SALMOD (USGS), a spatially explicit and size/stage structured population dynamics model that predicts the growth, survival, and movement of salmon in freshwater systems. We calibrated SALMOD to adult over-summer mortality and smolt out-migration. We ran SALMOD for the period 2010-2099, using WEAP output for carbon emission scenarios A2 and B1, for six global circulation models. We will present results on the potential population trends of Chinook salmon, and the life history stages most susceptible to climate change effects. We are currently using WEAP21 and SALMOD to evaluate management options to ameliorate these impacts.

Thompson, L. C., M.I. Escobar, C.M. Mosser, D.R. Purkey, D. Yates, and P.B. Moyle (2012). "Water management adaptations to prevent loss of spring-run Chinook salmon in California under climate change." J. Water Resour. Plann. Manage. 138(5): 14.

Spring-run Chinook salmon (Oncorhynchus tshawytscha) are particularly vulnerable to climate change because adults over-summer in freshwater streams before spawning in autumn. We examined streamflow and water temperature regimes that could lead to long-term reductions in spring-run Chinook salmon (SRCS) in a California stream and evaluated management adaptations to ameliorate these impacts. Bias-corrected and spatially downscaled climate data from six general circulation models and two emission scenarios for the period 2010–2099 were used as input to two linked models: a water evaluation and planning (WEAP) model to simulate weekly mean streamflow and water temperature in Butte Creek, California that were used as input to SALMOD, a spatially explicit and size/stage structured model of salmon population dynamics in freshwater systems. For all climate scenarios and model combinations, WEAP yielded lower summer base flows and higher water temperatures relative to historical conditions, while SALMOD yielded increased adult summer thermal mortality and population declines. Of management adaptations tested, only ceasing water diversion for power production from the summer holding reach resulted in cooler water temperatures, more adults surviving to spawn, and extended population survival time, albeit with a significant loss of power production. The most important conclusion of this work is that long-term survival of SRCS in Butte Creek is unlikely in the face of climate change and that simple changes to water operations are not likely to dramatically change vulnerability to extinction.

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http://ascelibrary.org/doi/abs/10.1061/%28ASCE%29WR.1943-5452.0000194%20?journalCode=jwrmd5

Thomson, J. R., W. J. Kimmerer, et al. (2010). "Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary." Ecological Applications 20(5): 1431-1448.

We examined trends in abundance of four pelagic fish species (delta smelt, longfin smelt, striped bass, and threadfin shad) in the upper San Francisco Estuary, California, USA, over 40 years using Bayesian change point models. Change point models identify times of abrupt or unusual changes in absolute abundance (step changes) or in rates of change in abundance (trend changes). We coupled Bayesian model selection with linear regression splines to identify biotic or abiotic covariates with the strongest associations with abundances of each species. We then refitted change point models conditional on the selected covariates to explore whether those covariates could explain statistical trends or change points in species abundances. We also fitted a multispecies change point model that identified change points common to all species. All models included hierarchical structures to model data uncertainties, including observation errors and missing covariate values.

There were step declines in abundances of all four species in the early 2000s, with a likely common decline in 2002. Abiotic variables, including water clarity, position of the 2 per thousand isohaline (X2), and the volume of freshwater exported from the estuary, explained some variation in species' abundances over the time series, but no selected covariates could explain statistically the post-2000 change points for any species

Thomson-Becker, E. and S. N. Luoma (1985). "Temporal fluctuations in grain size, organic materials and iron concentration in intertidal surface sediment of San Francisco Bay." Hydrobiologia 129: 91-107.

Thorne, K., J.Y. Takekawa, K. Spragens, D. Elliott-Fisk, G. Wylie, and W. Perry (2010). Evaluating the effects of projected sea-level rise on salt marsh endemic listed species of the San Pablo Bay National Wildlife Refuge, CA. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Coastal salt marshes and estuaries are projected to be highly impacted by climate change and sea level rise scenarios developed by the Intergovernmental Panel on Climate Change. San Francisco Bay, CA estuary has been highly modified due to urban development and landscape modification resulting in over 80% of wetland loss. This intense modification of salt marshes has resulted in habitat loss for endemic endangered species. The San Pablo Bay National Wildlife Refuge is the second largest wildlife refuge in the San Francisco Bay and is important habitat for listed species, including the salt marsh harvest mouse (Reithrodontomys raviventris), California black rail (Laterallus jamaicensis coturniculus),and California clapper rail (Rallus longirostris obsoletus). Maintenance of habitat is crucial to the success of endangered species, but it remains unknown how sea level rise may impact the amount and quality of habitat. Remaining tidal salt marsh fragments are often bordered on the upland side by development, reducing the ability of marshes to shift upland as sea level rise increases. The objective of this USGS National Climate Change Wildlife Science Center funded research is to quantify and evaluate the impact of sea level rise on the San Pablo Bay National Wildlife Refuge habitats and resident listed species. This study synthesized field RTK GPS elevation data, plant community characteristics and habitat information to develop sea level rise impact models. Preliminary spatial models show that high tide and storm events coupled with small increases in sea level could initially have a greater impact to resident endangered species. This poster will summarize our preliminary 2008 - 2010 results and ongoing research objectives.

Thrasher, B., S. Loarie, and P. Duffy (2010). PRISM-based downscaled global climate models for California climate change impact research. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The PRISM 1km climatology is one of the most widely used historic climate datasets for understanding regional level climate patterns across the United States. We used PRISM to statistically downscale and bias corrected Global Climate Model simulations from 16 models and 3 emission scenarios across California. An advantage of the suite of simulations presented here of alternative regional climate simulations with similar spatial resolutions is that variability among the 16 models can be used to summarize uncertainty in climate projections. We describe patterns of climate projections and uncertainty across CA and discuss applications to climate impact modeling in the San Francisco Bay Area.

Thrasher, B. (2010). Statistical downscaling of CMIP5 global climate model simulations for use in Bay Area regional impact studies. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Global climate models (GCM) encapsulate our best understanding of the physics of the climate system, but they operate at spatial scales too coarse to meet the needs of societal impacts researchers and decision makers. In an effort to aid these groups in their endeavors, we are performing systematic spatial downscaling of the global simulations now being generated by modeling groups around the world for the Coupled Model Intercomparison Project (CMIP5). Two statistical downscaling

methods are being utilized to add spatial detail based upon fine-scale gridded observations of historical climate: the “Bias-Corrected Constructed Analogs” method and the “Bias-Corrected Spatial Downscaling method.” We will downscale several hundred simulations from all participating models and from several Representative Concentration Pathways. The resulting library of downscaled climate projections will be at a spatial resolution of 12 km x 12 km and will include both monthly and daily averages of minimum and maximum surface temperature, as well as precipitation.

Tigan, G. (2010). Influence of saltwater on longfin smelt embryo and early life-stage development in culture. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Titus, R. G., M. C. Volkoff, et al. (2004). Use of Otolith Microstructure to Estimate Growth Rates of Juvenile Chinook Salmon from a Central Valley, California Stock. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 181-202.

We compared two approaches to back-calculation with otolith microstructure to develop a method for accurately estimating growth rates of juvenile fall-run Chinook salmon Oncorhynchus tshawytscha in California's Central Valley. Total otolith width was a strong determinant of fork length (FL) in linear regressions used to determine the y-intercept in the fish size-otolith size relationship in two study groups of Chinook salmon. The Fraser-Lee back-calculation model estimated FL at first feeding in both study groups that did not differ significantly from lengths of first-feeding Chinook salmon in a reference group. In comparison, the biological-intercept method produced back-calculated lengths that were significantly greater in one study group than lengths of first-feeding Chinook salmon in the reference group. Chinook salmon emergence dates, estimated from counts of daily growth increments beyond the first-feeding check, corresponded with observed emergence periods in the river and hatchery populations from which the study groups were sampled. Size-at-age relationships were well described by a power function in both study groups, where mean FL over time approached an apparent asymptote at approximately 80 mm after 90 d postemergence. Growth rate estimates, using back-calculated size from the Fraser-Lee model, averaged 0.50 mm/d in one study group and 0.43 mm/d in the other study group. These estimates fell within the range of previous growth rate estimates for juvenile Chinook salmon in Central Valley riverine, floodplain, and delta environments and were about 2.5 times higher on average than an estimate for the San Francisco Estuary and about 2.3 times lower on average than estimates from the Strait of Georgia. We discuss the utility of otolith microstructure to not only estimate growth rates, but also to reconstruct emergence-date distributions in cohorts of emigrating juvenile Chinook salmon for stock identification purposes.

Toft, J. D. (2002). "New records of crustaceans (Amphipoda,Isopoda) in the Sacramento/San Joaquin delta, California and application of criteria for introduced species." Journal of crustacean biology 22(1): 190-200.

The amphipod Crangonyx floridanus and the isopods Caecidotea racovitzai and Asellus hilgendorfii were discovered in the Sacramento/San Joaquin Delta, California, U.S.A. We applied Chapman and Carlton's (1994) criteria for determining introduced species to test whether these species are non-indigenous to the delta. The majority of the attributes scored positive, indicating that these species are non-indigenous. These populations appear to be firmly established, as they occurred at a variety of freshwater wetland habitats throughout a one-year study. The species are briefly described, and distinguished from similar native and non-indigenous species known to exist in the surrounding area.

Toft, J. D., C.A. Simenstad, J.A. Cordell, and L.F. Grimaldo (2003). "The effects of introduced water hyacinth on habitat structure, invertebrate assemblages, and fish diets." Estuaries and Coasts 26(3): 746-758.

The South American floating aquatic plant water hyacinth (Eichhornia crassipes) has a history of worldwide invasions, including a 1904 introduction into the Sacramento-San Joaquin Delta, California. The native pennywort (Hydrocotyle umbellata) occupies similar habitats in the Delta and is extensively used by resident invertebrates and fish. We sought to discover if an invader would be functionally equivalent to the native plant, by asking whether the encroaching hyacinth modified the invertebrate assemblage structure and fish-invertebrate food web relative to pennywort. We sampled epiphytic, epibenthic, and benthic invertebrates, and plant canopy insects in patches of hyacinth and pennywort, and analyzed fish diets at three sites in the Delta during 1998. We also measured habitat structure (leaf density, root biomass, and surface area). In 1999, following control and absence of hyacinth, we again measured epiphytic invertebrates in pennywort. We found differences between hyacinth and pennywort in structure, associated invertebrates, and fish diets. Most measurements inferred functional non-equivalency between hyacinth and pennywort, although some functional equivalency and natural variation existed. Leaf and insect densities were significantly higher in pennywort and there were also significant differences in insect assemblage compositions. Hyacinth roots in the water column had significantly more surface area. Densities of epibenthic and benthic aquatic invertebrates were typically greater in pennywort and taxonomic compositions of aquatic invertebrate assemblages showed significant differences. Amphipods and isopods living epiphytically in the root masses were particularly abundant, including several newly discovered introduced species: the amphipod Crangonyx floridanus and the isopods Caecidotea racovitzai and Asellus hilgendorfii. The native amphipod Hyalella azteca was more abundant in pennywort and heavily preyed upon by fish, while the non-indigenous C. floridanus was more abundant in hyacinth and not prevalent in fish diets. The introduction of hyacinth to the Delta has caused significant ecological alterations in the surrounding community, due to hyacinth being functionally different from native patches of pennywort.

Tompkins, M., J. Thomas, A. Falzone, R. Storesund, W. Qin, and H. Reith (2010). Floodplain reconnection potential on the San Joaquin River at Great Valley Grassland State Park, Merced County, California. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Great Valley Grasslands State Park (GVGSP) preserves one of the few intact native grasslands (including stands of native bunchgrass prairie) in the California Central Valley. However, these grasslands have been invaded by exotic species, which has been attributed at least in part to the disconnection of the grasslands from inundation by high flows from the San Joaquin River. The California Department of Parks and Recreation is investigating the potential to reconnect the San Joaquin River and portions of GVGSP to restore floodplain-dependent fluvial geomorphic and ecological processes, with the primary intention of controlling exotic species invasion and recreating more natural ecological conditions in the park. The Project Team utilized hydraulic models and geospatial analyses to evaluate the potential for floodplain reconnection by assessing the range of flood stages and flood frequencies required to restore an adequate flooding regime to the park, determining preliminary sizing and preferred locations for two levee breaches, quantifying the range of hydraulic forces likely to occur at the levee breaches, and characterizing the hydrodynamics on the inundated floodplain (including residence times of flood waters, extents and depths of flooding, and the potential for stranding of fish on the floodplain as waters recede.) The results of this investigation provide valuable insights on the range of considerations and potential benefits of floodplain reconnection in the Central Valley, an ecosystem restoration approach that is widely cited in ongoing efforts related to the Delta including the Bay Delta Conservation Plan (BDCP), the Delta Plan, and the Central Valley Flood Management Planning Program (CVFMP).

Topping, B. R. and J. S. Kuwabara (2003). "Dissolved nickel and benthic flux in South San Francisco Bay: A potential for natural sources to dominate." Bulletin of Environmental Contamination and Toxicology 71(1): 46-51.

The article cites a study on dissolved nickel and benthic flux in South San Francisco Bay in California. It states that nickel-rich serpentinite formations around the San Francisco Bay-estuary, particularly South Bay, are eroded, transported and accumulated in estuarine sediments, providing a natural source of nickel. Although the areal coverage of these formations is not pronounced, their potential importance is suggested by the spatial distribution of serpentinite throughout nearly all watersheds surrounding South Bay. This non-anthropogenic

source, as well as the intermittent exceedances in South Bay nickel concentrations, has motivated a reexamination of potential nickel-transport processes and regulatory strategies.

Townsend, H., M. Bauer, L.R. Brown, and F. Feyrer (2010). An ecosystem model for testing potential causes of the San Francisco Estuary pelagic organisms decline. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Townsend, H., M. Bauer, and L.R. Brown (2010). An ecotrophic-based model of the Sacramento-San Joaquin Delta. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Ecosystem modeling provides a useful framework for organizing ecosystem data. Investigating the quality of the data in such models provides an objective measure of the model’s ability to replicate the system and how management decisions may affect ecosystem functionality. We have developed a mass-balanced trophic model for the Sacramento-San Joaquin Delta using Ecopath with Ecosim (EwE 6) software to explore ecosystem dynamics of the pelagic organism decline. The model uses parameters such as biomass, production, and mortality estimates of 40 functional groups, including birds, fish, benthic invertebrates, zooplankton, phytoplankton, and detritus. Model parameters were calculated from published and unpublished local data, taken from the literature, or, if necessary, estimated. We use this initial data in the static, mass-balanced Ecopath model to establish the initial conditions for the model. We then used these initial conditions in a simulation modeling approach to explore ecosystem drivers. To investigate the quality of the data for initial conditions, we use Monte Carlo simulations to allow a subset of the initial parameters to vary randomly by 50% and determine what percent of the simulation runs deviate from the general trends. Monte Carlo simulations for parameters that result in high deviation suggest that the model is sensitive to these parameters and improvements in monitoring and research for these parameters would improve our understanding of Delta ecosystem dynamics.

Trenham, P. C., H.B. Shaffer, and P.B. Moyle. (1998). "Biochemical identification and assessment of population subdivision in morphometrically similar native and invading smelt species (Hypomesus) in the Sacramento-San Joaquin Estuary, California." Transactions of the American Fisheries Society 127(3): 417-424.

The invasion of the Sacramento–San Joaquin estuary by the wakasagi Hypomesus nipponensis poses threats of competition and hybridization with the endemic delta smelt Hypomesus transpacificus, a species listed as threatened by federal and state agencies. Small individuals of these species are difficult to distinguish morphologically, but correct identification is extremely important to avoid mistaking delta smelt for wakasagi under the limited take provisions of the federal endangered species act. Allozyme markers were used to identify 280 individual fish from several sites across the range of H. transpacificus. We used these results to document the current level of invasion by H. nipponensis, quantify levels of misidentification based on morphological characters, identify hybrid individuals, and estimate levels of gene flow in H. transpacificus. Wakasagi have spread throughout the Sacramento–San Joaquin estuary, and further monitoring will be necessary to determine the long-term consequences of their invasion on the native delta smelt. Our data suggest that when the level of uncertainty in morphological identification is high, biochemical identification is the safest way to identify fish. We identified only two F1 hybrid individuals, suggesting that although hybridization does occur, it is not a serious threat to delta smelt at the present time. Finally, estimates of θ based on four variable allozyme loci indicate that gene flow between our four sampled locations is very high in H. transpacificus.

Triboli, K., A. Mueller-Solger, and M. Vayssieres (2003). The grind about sonicated chlorophyll (or: did a method change in 1998 affect EMP chlorophyll results?). IEP Newsletter. 16: 12.

Truan, M. (2010). Implications of changing salmon dynamics to the Butte Creek food web. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Because they accumulate the majority of their biomass in the ocean, salmon deliver large quantities of marine-derived nutrients to upstream ecosystems during spawning, representing an important subsidy to recipient freshwater and riparian food webs. In addition, terrestrial carnivores and scavengers transport nutrients in the form of fish carcasses and digesta from fresh water to land, enriching the riparian food chain and influencing the biology of major terrestrial consumers. Loss of these ecosystem subsidies may have profound implications for aquatic-terrestrial food webs in recipient watersheds. As part of a larger project modeling climate change related modifications to hydrological and water temperature regimes for spring-run Chinook salmon in Butte Creek, CA (see previous two abstracts), we convened an Expert Panel to develop a conceptual model of the Butte Creek food web, discuss the relative importance of salmon-derived nutrients to the Butte Creek food web, and evaluate the potential for changes to the food web under model assumptions. To assist in this effort, species information was compiled through literature searches, consultation with experts, and remote camera image analysis. Preliminary field work indexed the relative abundance of marine-derived nutrients in selected plant and animal species using stable isotope analysis. Taxonomic groups sampled included spring-run Chinook salmon, benthic macroinvertebrates, epilithic material, riparian plants, terrestrial arthropods, amphibians, reptiles, birds, and mammals. Results suggest that salmon-derived nutrients comprise a significant nutrient subsidy in spawning reaches compared with non-spawning reaches and that loss of these nutrients may have substantial effects on the structure and function of the Butte Creek food web. These insights emphasize the value of management efforts to maintain and enhance viable habitat for spring-run Chinook salmon in Bay-Delta tributaries, since losses of this keystone species may have significant and widespread effects on ecosystem structure and function.

Trulio, L., J. Sokale, and H. White (2010). Public access and waterbirds: Research that managers can use. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Public access opportunities in and adjacent to wildlife habitats are increasing due to agency mandates and public demand. Projects, such as the South Bay Salt Pond Restoration Project, have the dual, and potentially-competing, objectives of providing quality public access and supporting healthy wildlife populations. We have undertaken a series of studies designed to assist managers throughout the San Francisco Bay area in meeting both these goals. Current findings focus on foraging shorebird and waterfowl response to human use of trails located on levees adjacent to foraging habitat. At 3 tidal locations around the Bay, we observed shorebirds foraging on mudflats adjacent to trails and adjacent to sites without trails. Despite major differences in human activity, we found no statistically significant differences in the number of shorebirds, species richness, or proportion of shorebirds foraging at trail versus non-trail sites. When comparing weekdays to weekend days, the number of shorebirds showed a decrease as use at trail sites increased. This study provides information on foraging shorebirds in response to human use at well-established trails. We are currently investigating shorebird response to human use of trails at sites not previously open to the public. We also studied waterfowl response to experimental trail use at 4 former salt ponds in the South Bay not open to public access. Findings showed that diving ducks moved between 106m and 140m away from levees in response to trail walkers adjacent to the ponds. At distances up to 120m from the trail, the number of birds and species richness were statistically significantly lower after walkers passed compared to before the disturbance. Managers can use these data in trail location and design. We are extending this study to investigate waterfowl response to well-established trails, adding to the information on how birds respond to different trail use conditions.

Tsai, P., R. Hoenicke, et al. (2002). "Atmospheric concentrations and fluxes of organic compounds in the northern San Francisco estuary." Environmental Science and Technology 36: 4741-4747.
A study was conducted to measure atmospheric concentrations of PAHs and PCBs and estimate their fluxes between air and water in the northern San Francisco Estuary. Ambient air samples were, collected once every 12 days at a single sampling site in Concord, CA, from June to November 2000, using a modified high-volume air-sampling device equipped with glass fiber filters and polyurethane foam.

Concentrations of total PAHs and PCBs ranged from 5.7 to 56 and 0.17 to 0.32 ng/m(3), respectively. PAHs and PCBs in the ambient air were predominantly in the vapor phase (83-99%). Gaseous fluxes of PAHs in the estuary showed high seasonal variation, ranging from 110 ng(.)m(-2.)day(-1) efflux in August to 1050 ng(.)m(-2.)day(-1): influx in November. Gaseous PCBs showed consistent net, volatilization (2.2-24 ng(.)m(-2.)day(-1)) for this period. Particle settling contributed estimated net deposition fluxes of 45-960 ng(.)m(-2.)day(-1) for PAHs and 0.39-2.1 ng(.)m(-2.)day(-1) for PCBs. Combining these fluxes, PAHs were either deposited to or lost from the Estuary via the atmosphere, depending on the month. In contrast, there consistently was net emission of PCBs from the estuary to the atmosphere.

Tuil, J., A. Casas, D. Riaño, J. Greenberg, and S.L. Ustin (2010). Levee stability parameterization from airborne LiDAR and hyperspectral sensors in the Sacramento-San Joaquin River Delta. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The Sacramento-San Joaquin Delta has approximately 1,100 miles of levees, which supports agriculture, maintains water exports and protects urban areas and infrastructures. The integrity of these levees is of major importance to land managers and policy makers given the consequence of levee failure. External evidence of levee instability such as slumping at the toe or sliding areas at the top, e.g. due to subsidence, can be used to detect levees prone to failure through a characterisation of the superficial levee configuration. A methodology to quantify levee stability and its relation with vegetation occurrence and distribution for a 16 km reach of the Sacramento River is investigated using high resolution airborne LiDAR combined with hyperspectral imagery. Levee profiles were extracted from a Digital Terrain Model (DTM) generated from the high resolution (1m rasterization) LiDAR data. Geometric structural parameters were calculated including levee crown width, height, width and slope. Deviation of these parameters from the levee design standards, therefore, can be used as a levee stability index. To study the influence of vegetation structure on levee stability, a Digital Surface Model (DSM) from the LiDAR data was generated. We extracted the same surface profiles and calculated vegetation height and density. Vegetation species were identified using a species map obtained from hyperspectral imagery and used to investigate the impact of certain species upon the structural condition of the levees. The combination of LiDAR and Hyperspectral data provides not only an effective method to assess the external state of the levees using airborne remote sensing information and detect prone to failure areas, but an improved insight into the impact of vegetation upon the structural condition of a levee system.

Tuohy, W. S. (1993). "Characterizing the San Francisco Estuary: a case study of science management in the National Estuary Program." Coastal Management 21: 113-129.
The San Francisco Estuary Project sought to "characterize" environmental conditions in the San Francisco Bay and Sacramento--San Joaquin Delta. This task involved systematic description and analysis of conditions, to provide the scientific basis for policy reform. The focus of this paper is on activities of environmental scientists who participated on the project's Technical Advisory Committee (TAC), and their involvement on issue-oriented subcommittees. Special attention is given to interest group representation, TAC and subcommittee activities, fulfillment of assigned tasks, and linkages to subsequent policy deliberations. Findings include only partial success in sustaining broad scientific representation, achieving peer review, and gaining access to policy deliberations, but noteworthy benefits for political legitimization and public education. In conclusion features of this project are highlighted for relevance to comparable efforts.

Tuohy, W. S. (1993). "Neglect of market incentives in local environmental planning: a case study in the National Estuary Program." Coastal Management 22: 81-95.

Turner, J. (1990). Observations on the time, location, and possible factors determining the size of the young bass index in the Sacramento-San Joaquin Estuary.

Turner, J. L., and D.W. Kelley, Ed. (1966). Ecological Studies of the Sacramento-San

Joaquin Delta Part II: Fishes of the Delta. Fish Bulletin. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game.
In July 1961 the Delta Fish and Wildlife Protection Study began an investigation of the ecology of the Sacramento-San Joaquin estuary in California. Our investigations were designed to answer specific questions raised by water development plans proposed for the estuary, and to provide a background of information that could be used to evaluate these plans.

We have annually prepared a progress report, and more recently published the first volume of our ecological studies; a series of eight papers on fishes of San Pablo and Suisun bays, and of zooplankton and zoobenthos of the Delta and San Pablo and Suisun bays.

This is the second volume of our ecological studies. It consists of 12 individual papers about the distribution, relative abundance, food and spawning habits of fishes in the Sacramento-San Joaquin Delta.

In 1965, after evaluation of four alternative Delta water transfer concepts, the peripheral canal plan was selected as the only plan with the opportunity to both protect and enhance these resources. Our present studies are being directed toward learning how to operate with peripheral canal to use these opportunities.

Turner, J. L., and T.C. Farley (1971). "Effects of temperature, salinity, and dissolved oxygen on the survival of striped bass eggs and larvae." California Fish and Game 57(4): 268-273.
Laboratory experiments were conducted on the effects of salinity, temperature, and dissolved oxygen on the survival of artificially spawned striped bass eggs and larvae. Egg survival in salinities greater than about 1,000 ppm TDS, especially at higher temperatures, are greatly reduced if eggs are not water hardened in fresh water. Moderate reductions in dissolved oxygen (to 4 to 5 mg/liter) adversely affect the percent hatch of eggs and have a detrimental effect on larval survival.

Turner, J. L., and H.K. Chadwick (1972). "Distribution and abundance of young-of-the-year striped bass, Morone saxatilis, in relation to river flow in the Sacramento-San Joaquin Estuary." Transactions of the American Fisheries Society 101: 442-452.
Annual distribution and abundance of young-of-the-year striped bass were measured from 1959 to 1970 in the Sacramento-San Joaquin estuary. Annual abundance of young bass in late summer was closely related to the amount of river flow in June-July into the estuary (r = 0.89). Highly significant correlations existed between striped bass abundance and salinity and water diverted from the estuary, both of which were mutually related to the amount of river flow. Six mechanisms which may control these relationships are discussed. Annual striped bass distribution in the estuary was also related to river flow (r = -0.93) and salinity (r = 0.88) with bass being farther upstream in years of low runoff and high salinity.

Turner, J. L. (1976). "Striped bass spawning in the Sacramento and San Joaquin rivers in central California from 1963 to 1972." California Fish and Game 62: 106-118.

Tyler, A. C., J. G. Lambrinos, et al. (2007). "Nitrogen inputs promote the spread of an invasive marsh grass." Ecological Applications 17(7): 1886-1898.
Excess nutrient loading and large-scale invasion by nonnatives are two of the most pervasive and damaging threats to the biotic and economic integrity of our estuaries. Individually, these are potent forces, but it is important to consider their interactive impacts as well. In this study we investigated the potential limitation of a nonnative intertidal grass, Spartina alterniflora, by nitrogen (N) in estuaries of the western United States. Nitrogen fertilization experiments were conducted in three mud-flat habitats invaded by S. alterniflora in Willapa Bay, Washington, USA, that differed in sediment N. We carried out parallel experiments in San Francisco Bay, California, USA, in three habitats invaded by hybrid Spartina (S.

alterniflora x S. foliosa), in previously unvegetated mud flat, and in native S. foliosa or Salicornia virginica marshes. We found similar aboveground biomass and growth rates between habitats and estuaries, but end-of-season belowground biomass was nearly five times greater in San Francisco Bay than in Willapa Bay. In Willapa Bay, aboveground biomass was significantly correlated with sediment N content. Addition of N significantly increased aboveground biomass, stem density, and the rate of spread into uninvaded habitat (as new stems per day) in virtually all habitats in both estuaries. Belowground biomass increased in Willapa Bay only, suggesting that belowground biomass is not N limited in San Francisco Bay due to species differences, N availability, or a latitudinal difference in the response of Spartina to N additions. The relative impact of added N was greater in Willapa Bay, the estuary with lower N inputs from the watershed, than in San Francisco Bay, a highly eutrophic estuary. Nitrogen fertilization also altered the competitive interaction between hybrid Spartina and Salicornia virginica in San Francisco Bay by increasing the density and biomass of the invader and decreasing the density of the native. There was no significant effect of N on the native, Spartina foliosa. Our results indicate that excess N loading to these ecosystems enhances the vulnerability of intertidal habitats to rapid invasion by nonnative Spartina sp.

Ulrich, P., and D. Sedlak (2010). Assessment of the potential for using iron amendments to decrease net methylmercury exports from tidal wetlands in San Francisco Bay. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Many wetland restoration projects are planned or underway within the Bay-Delta System, including a commitment to restore around 40,000 acres in the Delta by 2030. Because tidal wetlands can be important sources of methylmercury (MeHg) there is concern that wetland restoration will increase MeHg loading to sensitive aquatic ecosystems. In recognition of this potential problem, the Delta Basin Plan and mercury TMDL establish a goal of no significant increases of MeHg due to restoration activities. While these are laudable goals, the absence of landscape-scale approaches for to controlling MeHg production in wetlands puts restoration in conflict with mercury control activities. Amendment of wetland sediments with iron offers a potential means of limiting the concentration of dissolved, bioavailable mercury-sulfur complexes in the sediment porewater to the methylating bacteria. We previously demonstrated the efficacy of this approach in laboratory experiments with sediment slurries. To better understand the effect of iron amendments on in situ tidal marsh biogeochemistry, microcosm and field studies have been conducted at a tidal salt marsh along the Petaluma River. Before and after amending the sediments with iron, porewater from pickleweed-dominated sediments on the high marsh plain were analyzed for iron, sulfur, and methylmercury. Seasonal variations in MeHg production and the effect of iron addition on sulfur and iron cycling and MeHg production were evaluated by following concentration changes over time. Understanding these cycles and the length of time for which iron amendments are effective is an important step in evaluating the potential for using this approach to help reduce MeHg production from the restoration of tidal wetlands.

Uncles, R. J., and D.H. Peterson (1995). "A computer model of long-term salinity in San Francisco Bay: Sensitivity to mixing and inflows." Environment International 21(5 Water Modeling): 647-656.

A two-level model of the residual circulation and tidally-averaged salinity in San Francisco Bay has been developed in order to interpret long-term (days to decades) salinity variability in the Bay. Applications of the model to biogeochemical studies are also envisaged. The model has been used to simulate daily-averaged salinity in the upper and lower levels of a 51-segment discretization of the Bay over the 22-y period 1967-1988. Observed, monthly-averaged surface salinity data and monthly averages of the daily-simulated salinity are in reasonable agreement, both near the Golden Gate and in the upper reaches, close to the delta. Agreement is less satisfactory in the central reaches of North Bay, in the vicinity of Carquinez Strait. Comparison of daily-averaged data at Station 5 (Pittsburg, in the upper North Bay) with modeled data indicates close agreement with a correlation coefficient of 0.97 for the 4110 daily values. The model successfully simulates the marked seasonal variability in salinity as well as the effects of rapidly changing freshwater inflows. Salinity variability is driven primarily by freshwater inflow.

The sensitivity of the modeled salinity to variations in the longitudinal mixing coefficients is investigated. The modeled salinity is relatively insensitive to the calibration factor for vertical mixing and relatively sensitive to the calibration factor for longitudinal mixing. The optimum value of the longitudinal calibration factor is 1.1, compared with the physically-based value of 1.0. Linear time-series analysis indicates that the observed and dynamically-modeled salinity-inflow responses are in good agreement in the lower reaches of the Bay.

Uncles, R. J. and D. H. Peterson (1996). "The long-term salinity field in San Francisco Bay." Continental Shelf Research 16(15): 2005-2039.
Data are presented on long-term salinity behaviour in San Francisco Bay, California. A two-level, width averaged model of the tidally averaged salinity and circulation has been written in order to interpret the long-term (days to decades) salinity variability. The model has been used to simulate daily averaged salinity in the upper and lower levels of a 51 segment discretization of the Bay over the 22-yr period 1967-1988. Monthly averaged surface salinity from observations and monthly-averaged simulated salinity are in reasonable agreement. Good agreement is obtained from comparison with daily averaged salinity measured in the upper reaches of North Bay. The salinity variability is driven primarily by freshwater inflow with relatively minor oceanic influence. All stations exhibit a marked seasonal cycle in accordance with the Mediterranean climate, as well as a rich spectrum of variability due to extreme inflow events and extended periods of drought. Monthly averaged salinity intrusion positions have a pronounced seasonal variability and show an approximately linear response to the logarithm of monthly averaged Delta inflow. Although few observed date are available for studies of long-term salinity stratification, modelled stratification is found to be strongly dependent on freshwater inflow; the nature of that dependence varies throughout the Bay. Near the Golden Gate, stratification tends to increase up to very high inflows. In the central reaches of North Bay, modelled stratification maximizes as a function of inflow and further inflow reduces stratification. Near the head of North Bay, lowest summer inflows are associated with the greatest modelled stratification. Observations from the central reaches of North Bay show marked spring-neap variations in stratification and gravitational circulation, being both stronger at neap tides. This spring-neap variation is simulated by the model. A feature of the modelled stratification is a hydsteresis in which, for a given spring-neap tidal range and fairly steady inflows, the stratification is higher progressing from neaps to springs than from springs to neaps. The simulated responses of the Bay to perturbations in coastal sea salinity and Delta inflow have been used to further delineate the time-scales of salinity variability. Simulations have been performed about low inflow, steady-state conditions for both salinity and Delta inflow perturbations. For salinity perturbations a small, sinusoidal salinity signal with a period of 1yr has been applied at the coastal boundary as well as a pulse of salinity with a duration of one day. For Delta inflow perturbations a small, sinusoidally varying inflow signal with a period of 1 yr has been superimposed on an otherwise constant Delta inflow, as well as a pulse of inflow with a duration of one day. Perturbations in coastal salinity dissipate as they move through the Bay. Seasonal perturbations require about 40-45 days to from the coastal ocean to the Delta and to the head of South Bay. The response times of the model to perturbations in freshwater inflow are faster than this in North Bay and comparable in South Bay. In North Bay, time-scales are consistent with advection due to lower level, up-estuary transport of coastal salinity perturbations; for inflow perturbations, faster response times arise from both upper level, down-estuary advection and much faster, down-estuary migration of isohalines in response to inflow volume continuity. In South Bay, the dominant time-scales are governed by tidal dispersion.

Underwood, E. C., M. J. Mulitsch, et al. (2006). "Mapping invasive aquatic vegetation in the Sacramento-San Joaquin Delta using hyperspectral imagery." Environmental Monitoring and Assessment 121(1-3): 47-64.
The ecological and economic impacts associated with invasive species are of critical concern to land managers. The ability to map the extent and severity of invasions would be a valuable contribution to management decisions relating to control and monitoring efforts. We investigated the use of hyperspectral imagery for mapping invasive aquatic plant species in the Sacramento-San Joaquin Delta in the

Central Valley of California, at two spatial scales. Sixty-four flightlines of HyMap hyperspectral imagery were acquired over the study region covering an area of 2,139 km(2) and field work was conducted to acquire GPS locations of target invasive species. We used spectral mixture analysis to classify two target invasive species; Brazilian waterweed (Egeria densa), a submerged invasive, and water hyacinth (Eichhornia crassipes), a floating emergent invasive. At the relatively fine spatial scale for five sites within the Delta (average size 51 ha) average classification accuracies were 93% for Brazilian waterweed and 73% for water hyacinth. However, at the coarser, Delta-wide scale (177,000 ha) these accuracy results were 29% for Brazilian waterweed and 65% for water hyacinth. The difference in accuracy is likely accounted for by the broad range in water turbidity and tide heights encountered across the Delta. These findings illustrate that hyperspectral imagery is a promising tool for discriminating target invasive species within the Sacramento-San Joaquin Delta waterways although more work is needed to develop classification tools that function under changing environmental conditions.

Uriu-Adams, J. Y., C.K. Reece, L.K. Nguyen, B.J. Horvath, R. Nair, R.A. Barter, C.L. Keen (2001). "Effect of butyl benzyl phthalate on reproduction and zinc metabolism." Toxicology 159: 55-68.
Butyl benzyl phthalate (BBP) has been shown to be teratogenic. One mechanism contributing to the teratogenicity of several developmental toxicants, is chemical-induced changes in maternal zinc (Zn) metabolism which result in an increased synthesis of maternal liver metallothionein (Mt), and a subsequent reduction in Zn delivery to the conceptus. We investigated the effects of maternal BBP exposure on maternal-fetal Zn metabolism in Wistar rats. In study I, dams were gavaged with BBP (0, 250, 1000, 1500 or 2000 mg/kg) on gestation days (GD) 11 through 13, and killed on GD 20. Maternal toxicity was evident in the three highest dose groups. Embryo/fetal death and small pup weights and lengths were noted in the 2000 mg BBP/kg group. Fetuses in the 1500 and 2000 mg/kg groups were characterized by poor skeletal ossification, and a high frequency of cleft palate. Rib anomalies were observed in the three highest dose groups. Maternal liver Mt concentrations were only slightly elevated in the 1500 and 2000 mg/kg groups. In study II, dams treated as above, were gavaged with 65Zn and killed 18 h later. While the 2000 mg/kg group had high percentages of 65Zn in some maternal tissues, sequestration of 65Zn in maternal liver was not evident. Thus, BBP is not a strong inducer of Mt, and the teratogenicity of BBP does not appear to be due to alterations in maternal and/or embryonic Zn metabolism.

Utter, F., G. Milner, et al. (1989). "Genetic population structure of chinook salmon, Oncorhynchus tshawytscha, in the Pacific Northwest." Fishery Bulletin 87(2): 239-264.
Variation at 25 polymorphic protein coding loci was examined for 86 populations of chinook salmon, Oncorhynchus tshawytscha ranging from the Babine River in British Columbia to the Sacramento River in california. Substantial differences in allele frequencies identified patterns of genetic variability over the geographic range of the study. The following nine major genetically defined regions were formulated: 1) the Fraser River tributaries east of the Cascade Crest (no downstream drainages were sampled), 2) Georgia Strait, 3) Puget Sound, 4) a broad coastal region ranging from the west coast of Vancouver Island southward through northern California, 5) the Columbia River below The Dalles Dam, 6) the Columbia River above The Dalles Dam, 7) the Snake River, 8) the Klamath River, and 9) the Sacramento River. Populations sampled within a region tended to be genetically distinct from each other although they exhibited the general patterns of variability that defined the region.

Valoppi, L., and J. Bourgeois (2010). Overview of the South Bay Salt Pond Restoration Project and applied science for an Adaptive Management Plan. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The South Bay Salt Pond Restoration Project (www.southbayrestoration.org) is the largest wetlands restoration project on the West coast of the United States. It is unique not only for its size-- over 15,000 acres—but for its location in the middle of one of the nation’s largest urban areas, home to over 3 million people.

The Project is intended to restore and enhance wetlands in South San Francisco Bay while providing for flood management and wildlife-oriented public access and recreation. We have identified long-term alternatives for the Project, each representing a continuum toward different end-states: one end-state at 50% of the existing ponds converted to managed ponds for waterbirds and 50% restored to salt marsh habitat, and the other end of the continuum at 10% of the existing ponds converted to managed ponds and 90% restored to marsh habitat. The final mixture of managed ponds to salt marsh habitat will depend upon the outcome of the Adaptive Management Plan, which will be implemented over the next 50 years and will allow for lessons learned from earlier phases and applied studies to be incorporated into subsequent stages as management plans and designs of future actions are updated. This presentation will provide an overview of the key uncertainties in this first phase of the restoration, and how applied science is being used to address these uncertainties. Key uncertainties include sediment dynamics, bird use of changing habitats, effects on non-avian species, legacy mercury, water quality, invasive and nuisance species, and impacts of public access.

Van Eeten, M. J. G. and E. M. Roe (2002). Ecology, Engineering and Management: Reconciling Ecosystem Rehabilitation and Service Reliability. Oxford, Oxford University Press.

van Geen, A., N.J. Valette-Silver, S.N. Luoma, C.C. Fuller, M. Baskaran, F. Tera, and J. Klein (1999). "Constraints on the sedimentation history of San Francisco Bay from 14C and 10Be." Marine Chemistry 64(1-2): 29-38.

Industrialization and urbanization around San Francisco Bay as well as mining and agriculture in the watersheds of the Sacramento and San Joaquin rivers have profoundly modified sedimentation patterns throughout the estuary. We provide some constraints on the onset of these erosional disturbances with 10Be data for three sediment cores: two from Richardson Bay, a small embayment near the mouth of San Francisco Bay, and one from San Pablo Bay, mid-way between the river delta and the mouth. Comparison of pre-disturbance sediment accumulation determined from three 14C-dated mollusk shells in one Richardson Bay core with more recent conditions determined from the distribution of 210Pb and 234Th [Fuller, C.C., van Geen, A., Baskaran, M., Anima, R.J., 1999. Sediment chronology in San Francisco Bay, California, defined by 210Pb, 234Th, 137Cs, and 239,240Pu.] shows that the accumulation rate increased by an order of magnitude at this particular site. All three cores from San Francisco Bay show subsurface maxima in 10Be concentrations ranging in magnitude from 170 to 520×106 atoms/g. The transient nature of the increased 10Be input suggests that deforestation and agricultural development caused basin-wide erosion of surface soils enriched in 10Be, probably before the turn of the century.

van Geen, A. and S. N. Luoma (1993). "Trace Metals (Cd, Cu, Ni, and Zn) and Nutrients in Coastal Waters Adjacent to San Francisco Bay, California." Estuaries 16(3A): 559-566.

Samples collected in December 1990 and July 1991 show that dissolved Cd, Cu, Ni, and Zn distributions in the Gulf of the Farallones are dominated by mixing of two end-members: metal-enriched San Francisco Bay water and offshore California Current water. The range of dissolved metal concentrations observed is 0.2-0.9 nmol/kg for Cd, 1-20 nmol kg super(-1) for Cu, 4-16 nmol/kg for Ni, and 0.2-20 nmol/kg for Zn. Effective concentrations in fresh water discharged into San Francisco Bay during 1990-1991 (estimated by extrapolation to zero salinity) are 740-860 mu mol/kg for silicate, 21-44 mu mol/kg for phosphate, 10-15 nmol/kg for Cd, 210-450 nmol/kg for Cu, 210-270 nmol/kg for Ni, and 190-390 nmol/kg for Zn. Comparison with effective trace metal and nutrient concentrations for freshwater discharge reported by Flegal et al. (1991) shows that input of these constituents to the northern reaches of San Francisco Bay accounts for only a fraction of the input to Gulf of the Farallones from the estuary system as a whole. The nutrient and trace metal composition of shelf water outside a 30-km radius from the mouth of the estuary closely resembles that of California Current water further offshore. In contrast to coastal waters elsewhere, there is little evidence of Cd, Cu, Ni, and Zn input by sediment diagenesis in continental shelf waters of California.

van Geen, A. and S. N. Luoma (1999). "The impact of human activities on sediments of San Francisco Bay, California: an overview." Marine Chemistry 64(1-2): 1-6.
This note introduces a set of eight papers devoted to a detailed study of two sediment cores from San Francisco Bay with an overview of the region and a chronology of human activities. Data used in this study to constrain the range of sediment ages at different depths include super(234) Th , super(210) Pb , super(137) Cs , super(239,240) Pu , and super(10) Be concentrations in the sediment and the super(14) C age of shell fragments. In order of first detectable appearance in the record, the indicators of contamination that were analyzed include PAHs>Hg>Ag, Cu, Pb, Zn>DDT, PCB>foraminiferal Cd/Ca. This study also documents a large memory effect for estuarine contamination caused by sediment mixing and resuspension. Once an estuary such as San Francisco Bay has been contaminated, decades must pass before contaminant levels in surface sediment will return to background levels, even if external contaminant inputs have been entirely eliminated.

van Geen, A. and S. N. Luoma (1999). "A record of estuarine water contamination from the Cd content of foraminiferal tests in San Francisco Bay, California." Marine Chemistry 64(1-2): 57-69.
A five-year dissolved Cd time series from San Francisco Bay and adjacent coastal water shows that the composition of surface water towards the mouth of the estuary is determined largely by the effect of coastal upwelling. Cd concentrations inside and outside the estuary (0.2-1.0 nmol/kg) increase as Cd-rich deep water is advected to the surface near the coast during spring and summer. On average, the mean Cd concentrations inside San Francisco Bay (0.54 nmol/kg) during 1991-1995 was significantly higher than outside (0.35 nmol/kg), however. Surface samples collected throughout San Francisco Bay confirm an internal Cd source unrelated to river discharge. The Cd content of the test of a benthic foraminifer (Elphidiella hannai) in a dated sediment core from San Francisco Bay was measured to determine if the water column Cd enrichments in San Francisco Bay could be related to the rapid development of the watershed. The method is based on the observation that the Cd/Ca ratio of carefully cleaned tests of foraminifera is determined by the dissolved Cd content of overlying water at the time of test formation. Pre-industrial foraminiferal Cd/Ca ratios in the sediment core average 274 plus or minus 15 nmol/mol (n=19) nmol/mol. Foraminiferal Cd/Ca ratios increased to 386 plus or minus 33 nmol/mol (n=19) over the past several decades indicating a 40% increase in the mean Cd content of surface water in Central San Francisco Bay. We suggest that, in addition to Cd discharges into the estuary, indirect consequences of agricultural development in the Central Valley of California could have contributed to this increase. This new method to reconstruct estuarine contamination is not affected by some of the processes that complicate the interpretation of changes in bulk sediment metal concentrations.

van Geen, A., N. J. Valette-Silver, et al. (1999). "Constraints on the sedimentation history of San Francisco Bay from 14C and10Be." Marine Chemistry 64(1-2): 29-38.
Industrialization and urbanization around San Francisco Bay as well as mining and agriculture in the watersheds of the Sacramento and San Joaquin rivers have profoundly modified sedimentation patterns throughout the estuary. We provide some constraints on the onset of these erosional disturbances with super(10) Be data for three sediment cores: two from Richardson Bay, a small embayment near the mouth of San Francisco Bay, and one from San Pablo Bay, mid-way between the river delta and the mouth. Comparison of pre-disturbance sediment accumulation determined from three super(14) C -dated mollusk shells in one Richardson Bay core with more recent conditions determined from the distribution of super(210) Pb and super(234) Th [Fuller, C.C., van Geen, A., Baskaran, M., Anima, R.J., 1999. Sediment chronology in San Francisco Bay, California, defined by super(210) Pb , super(234) Th , super(137) Cs , and super(239,240) Pu .] shows that the accumulation rate increased by an order of magnitude at this particular site. All three cores from San Francisco Bay show subsurface maxima in super(10) Be concentrations ranging in magnitude from 170 to 520 x 10 super(6) atoms/g. The transient nature of the increased super(10) Be input suggests that deforestation and agricultural development caused basin-wide erosion of surface soils enriched in super(10) Be , probably before the turn of the century.

van Nieuwenhuyse, E. E. (2005). "Empirical model for predicting a catchment-scale

metric of surface water transit time in streams." Canadian Journal of Fisheries and Aquatic Sciences 62(3): 492-504.
Estimates of average water velocity (v sub(w)) extracted from tracer dye studies (v sub(dye)) or calculated from velocity-discharge relationships at continuous-flow gauges (v sub(gage)) were combined with catchment area (A) and other readily available data for 11 streams throughout the conterminous United States. The resulting data set (N = 305) represented broad ranges of A (65 - 62 419 km super(2)), mainstem length (L sub(max), 15.6-867 km) slope (S 0.14-11.5 m mu m super(-1)), and daily average discharge (Q, 0.09-634 m super(3) times s super(-1)). A catchment-scale metric of surface water transit time (T sub(w), L sub(max) v sub(dye) super(-1)) ranged from 0.3 to 40 days, averaging 7.2 days. A bivariate regression model using log sub(10) A and log sub(10) Q explained 83% of the variation in log sub(10) T sub(w) with an average precision of ~c49%. By contrast, a previously published model based on hydraulic geometry relationships overestimated T sub(w) by 100%. Application of this model to five streams nested in a ninth-order (omega = 9) catchment indicated that under dry (September) and wet (March), long-term (1954-2001) median flow conditions, v sub(w) increased with Q(v sub(w) proportional to Q super(0.3)) as far downstream as omega = 8 and then remained constant or declined. The slope of this longitudinal v sub(w)-Q relationship was three times greater than the expected value. Longitudinal velocity gradients in many streams may thus be much steeper than commonly assumed.

van Nieuwenhuyse, E. E. (2007). "Response of summer chlorophyll concentration to reduced total phosphorus concentration in the Rhine River (Netherlands) and the Sacramento-San Joaquin Delta (California, USA)." Canadian Journal of Fisheries and Aquatic Science 64: 1529-1542.

van Ark, N., J. Martinez, T.R.Sommer, and C.K. Reece (2010).
The Yolo Bypass Floodplain: A decade of discovery. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Veldhuizen, T. (1997). First annual IEP monitoring survey of the Chinese mitten crab in the delta and Suisun Marsh. IEP Newsletter. 10: 21-22.

Veldhuizen, T. (1998). "Monitoring juvenile Chinese mitten crabs in the Sacramento-San Joaquin Delta and Suisun Marsh." Outdoor California 58(3): 22.

Veldhuizen, T., and K. Hieb (1998). "What difference can one crab species make? The ongoing tale of the Chinese mitten crab and the San Francisco Estuary." Outdoor California 58(3): 19-21.

Veldhuizen, T., and K. Hieb (1998). What's new on the mitten crab front? IEP Newsletter. 11: 43.

Veldhuizen, T. (1999). Chinese mitten crab project work team. IEP Newsletter. 12: 7-8.

Veldhuizen, T., and S. Stanish (1999). Overview of the life history, distribution, abundance, and impacts of the Chinese mitten crab, Eriocheir sinensis. Sacramento, US Fish and Wildlife Service.

Veldhuizen, T. (2000). Predications and predications from a visiting mitten crab expert. IEP Newsletter. 13: 14-15.

Veldhuizen, T. (2001). "Life history, distribution, and impacts of the Chinese mitten crab, Eriocheir sinensis." Aquatic Invaders 12: 1-9.

Veldhuizen, T., and S. Foss (2001). Status of the Chinese mitten crab and control plans at the State and Federal fish facilities. IEP Newsletter. 14: 12-14.

Veldhuizen, T. (2010). Studies of the zebra mussel in a CVP reservoir and applications to DWR’s Mussel Management Program. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Veldhuizen, T. C. (2000). "Status of the Chinese mitten crab in California." Journal of Shellfish Research 19(1): 633-634.
The catadromous Chinese mitten crab (Eriocheir sinensis) is native to China and Korea and is also established in Europe and California. First collected in south San Francisco Bay in 1992, E. sinensis rapidly expanded in distribution and abundance. The current distribution in California is the San Francisco Estuary and the lower elevational reaches of the watershed. Based on the adverse impacts of the crab in Germany, E. sinensis poses ecological, economic, and health concerns in California. However, an assessment of the degree of impact in California is required. In 1999, the California Fish and Game Commission denied requests to commercially exploit the crab. Reasons for denial ranged from potential acceleration of dispersal to increased management costs to encouragement of future illegal introductions. Research and management of E. sinensis in California are facilitated through the Interagency Ecological Program's (IEP) Chinese mitten crab Project Work Team. For additio! nal information, visit the IEP website at http://www.water.ca.gov/iep/docs/IEP-ORG_11-15-12.pdf

Vella, M., C. Nelson, and J.L. Conrad (2010). Patterns in largemouth bass diet composition in the Sacramento-San Joaquin Delta
Delta Science Council Conference Poster.

Venkatesan, M. I., R.P. de Leon, A. van Geen, and S.N. Luoma (1999). "Chlorinated hydrocarbon pesticides and polychlorinated biphenyls in sediment cores from San Francisco Bay." Marine Chemistry 64(1-2): 85-97.
Sediment cores of known chronology from Richardson and San Pablo Bays in San Francisco Bay, CA, were analyzed for a suite of chlorinated hydrocarbon pesticides and polychlorinated biphenyls to reconstruct a historic record of inputs. Total DDTs (DDT=2,4′- and 4,4′-dichlorodiphenyltrichloroethane and the metabolites, 2,4′- and 4,4′-DDE, -DDD) range in concentration from 4–21 ng/g and constitute a major fraction (>84%) of the total pesticides in the top 70 cm of Richardson Bay sediment. A subsurface maximum corresponds to a peak deposition date of 1969–1974. The first measurable DDT levels are found in sediment deposited in the late 1930's. The higher DDT inventory in the San Pablo relative to the Richardson Bay core probably reflects the greater proximity of San Pablo Bay to agricultural activities in the watershed of the Sacramento and San Joaquin rivers. Total polychlorinated biphenyls (PCBs) occur at comparable levels in the two Bays (<1–34 ng/g). PCBs are first detected in sediment deposited during the 1930's in Richardson Bay, about a decade earlier than the onset of detectable levels of DDTs. PCB inventories in San Pablo Bay are about a factor of four higher in the last four decades than in Richardson Bay, suggesting a distribution of inputs not as strongly weighed towards the upper reaches of the estuary as DDTs. The shallower subsurface maximum in PCBs compared to DDT in the San Pablo Bay core is consistent with the imposition of drastic source control measures for these constituents in 1970 and 1977 respectively. The observed decline in DDT and PCB levels towards the surface of both cores is consistent with a dramatic drop in the input of these pollutants once the effect of sediment resuspension and mixing is taken into account.

Vicuna, S., E. P. Maurer, et al. (2007). "The sensitivity of California water resources to climate change scenarios." Journal of the American Water Resources Association 43(2): 482-498.
Using the latest available General Circulation Model (GCM) results we present an assessment of climate change impacts on California hydrology and water resources. The approach considers the output of two GCMs, the PCM and the HadCM3, run under two different greenhouse gas (GHG) emission scenarios: the high emission A1fi and the low emission B1. The GCM output was statistically downscaled and used in the Variable Infiltration Capacity (VIC) macroscale distributed hydrologic model to derive inflows to major reservoirs in the California Central Valley. Historical inflows used as inputs to the water resources model CalSim II were modified to represent the climate change perturbed conditions for water supply deliveries, reliability, reservoir storage and changes to variables of environmental concern. Our results show greater negative impacts to California hydrology and water resources than previous assessments of climate change impacts in the region. These

impacts, which translate into smaller streamflows, lower reservoir storage and decreased water supply deliveries and reliability, will be especially pronounced later in the 21st Century and south of the San Francisco bay Delta. The importance of considering how climate change impacts vary for different temporal, spatial, and institutional conditions in addition to the average impacts is also demonstrated.

Viers, J., G. Epke, S. Yarnell, and J. Mount (2010). Characterization of the unregulated spring snowmelt recession in the western Sierra Nevada, California and simulated changes in WEAP21 with regional climate warming from the Feather to the Kern River. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

We recently developed a conceptual model for the ecology and management of the spring snowmelt recession in Mediterranean-montane catchments. This conceptual model focused on three components of the Natural Flow Regime: magnitude, timing, and rate of change. Here we provide a model definition and develop synthetic hydrographs of the spring snowmelt recession for unregulated catchments of the Sierra Nevada, California. By modeling the exponential decay of snowmelt pulses, we explore empirical evidence for stationarity found in unregulated rivers in contrast with regulated river systems. Lastly, we show the results of spring snowmelt recession dynamics for climate altered hydrologies simulated in the WEAP21 rainfall-runoff model for the west-slope Sierra Nevada using increases in air temperature of 2, 4, and 6° C. Our results show that with regional climate warming the present rate of change in the snowmelt recession will decrease in part due to reductions in snowpack (i.e., decreases in magnitude) and increased duration of low flow conditions, but primarily due to a progressive negative shift in the timing of peak snowmelt. These results suggest potential impacts to freshwater and riparian organisms, which currently respond to the spring snowmelt period and accompanying flow conditions as a favorable window of opportunity for reproduction and population expansion.

Vines, C. A., F. J. Griffin, et al. (1999). Effects of creosote-treated wood on development in Pacific herring. Fish response to toxic environments., 1999. C. Kennedy and D. MacKinlay. Vancouver, BC, Department of Fisheries and Oceans: 141-144.

The effects of creosote-treated wood on early development in Pacific herring (Clupea pallasi) embryos were investigated in the laboratory and from a natural spawning site in San Francisco Bay. Embryos exposed to creosote-treated wood exhibited a variety of developmental abnormalities, including delayed development, degeneration of embryos, edema, decreased heart rate, cardiac arrhythmia, and alterations in embryonic movement within the chorian. In both laboratory and field exposed embryos, the hatching succss of exposed embryos was significantly decreased, with hatched larvae manifesting severe morphological deformities (scoliosis) and death shortly after hatching.

Vines, C. A., T. Robbins, et al. (2000). "The effects of diffusible creosote-derived compounds on development in Pacific herring (Clupea pallasi) " Aquatic Toxicology 51: 225-239.

The effects of diffusible creosote-derived compounds from weathered creosote-treated pilings on embryonic development in the Pacific herring were investigated. Parameters used to evaluate toxicity included embryonic development, cardiac function, embryo/larval activity (movement of developing embryos), hatching success, and larval morphology at hatch. For acute exposures, embryos were incubated in seawater containing either creosote-treated wood (creosote) or untreated wood (wood control), or seawater alone (control). All embryos adhering directly to creosote-treated wood and 40–50% of embryos not adhering to the creosote-treated wood failed to develop beyond the first few days of incubation. For surviving embryos, a 93% reduction in heart rate, and moderate to marked arrhythmia was observed. Surviving embryos also exhibited both an increase in frequency and an alteration in pattern of embryo/larval movement, with most embryos exhibiting tremors as compared with the vigorous movements of the control embryos. Cardiac function and embryo/larval movements of embryos exposed to untreated wood were not significantly different from controls. The hatching rate of embryos exposed to creosote was 90% lower than control embryos and 72.4% lower than embryos exposed to untreated wood, and the LC50 for hatching success was 0.05 mg/l. Partial hatching (incomplete hatch) was observed in 15–20% of embryos exposed to creosote. All of the hatched larvae exposed as embryos to creosote exhibited morphological deformities, including scoliosis, pericardial edema and/or ascites. Similar effects were observed in embryos collected from creosoted pilings in San Francisco Bay, with a 72% decrease in hatching success compared with embryos collected from the Bay and severely deformed larvae. To investigate the combined effects of creosote and salinity on hatching success, larval morphology, and cardiac function, embryos were exposed to a sublethal concentration of creosote (0.003 mg/l) at three salinities; sub-optimal (8 parts per thousand (ppt)), optimal (16 ppt), and high salinity (28 ppt). The presence of creosote decreased hatching success at all three salinities, but the effect was greatest at 8 ppt (34% reduction) and the least in 28 ppt (14% reduction). The increased incidence of morphological abnormalities was also smallest at the high salinity (10% compared with 24 and 33% in 8 and 16 ppt). While exposure to creosote resulted in reduced heart rates at all three salinities, no additive effect of creosote and salinity was observed.

Visintainer, T. A., S. M. Bollens, et al. (2006). "Community composition and diet of fishes as a function of tidal channel geomorphology." Marine Ecology Progress Series 321: 227-243.
We examined how channel system order and complexity influence fish community composition, abundance, and diet, by comparing first-through fourth-order channel systems at China Camp Marsh, San Francisco Estuary, California, USA. We sampled 6 channel systems (with replicates of the second- and fourth-order systems) bimonthly from July 2001 to May 2002 using modified fyke nets. We examined the diet of the 3 most common species that occurred consistently over time (seasonally): Atherinops affinis, Menidia beryllina, and Leptocottus armatus. Low-order (first- and second-order) systems supported higher densities of Gambusia affinis and Lucania parva, High-order (third- and fourth-order) systems supported greater species richness and densities of juveniles, including Clupea pallasi, than low-order systems. Prey taxa richness was greater for M beryllina and lower for L. armatus in the first-order system. There was a positive correlation between high-order channel systems and mean stomach fullness scores for L. armatus, and M beryllina had greater short-term consumption rates in high-order channel systems. Habitat heterogeneity, and specifically the presence of both low- and high-order channel systems, is necessary to accommodate early life stages, species-specific dietary requirements, and enhanced species richness of fishes at China Camp Marsh. Based on our results, we recommend that the processes and landscape scales that promote channel formation be considered in future salt marsh restoration projects.

Vogel, D. (2010). A synthesis of 22 telemetry studies to evaluate chinook salmon smolt migration and mortality in California’s Sacramento – San Joaquin Delta. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Vogel, D. A. and K. R. Marine (1992). "An assessment of the appraisal study of options for improving fish passage at Red Bluff Diversion Dam."

Vogel, T. M., R. S. Oremland, et al. (1982). "LOW-TEMPERATURE FORMATION OF HYDROCARBON GASES IN SAN-FRANCISCO BAY SEDIMENT (CALIFORNIA, USA)." Chemical Geology 37(3-4): 289-298.

Von Geldern, C. E. (1972). "A midwater trawl for threadfin shad, Dorosoma petenense." California Fish and Game 58: 268-276.

Vorster, P. (2010). Connecting the public to wild salmon in the San Francisco Bay-Delta watershed. 6th Biennial Bay–Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Wagner, R., M. Stacey, et al. (2011). "Statistical Models of Temperature in the Sacramento–San Joaquin Delta Under Climate-Change Scenarios and Ecological Implications." Estuaries and Coasts 34(3): 544-556.

Wagner, W., M. Stacey, and E. Van Nieuwenhuyse (2010). Thermal variability within a

complex branching estuarine system. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
California’s Sacramento-San Joaquin Delta is a complex assemblage of rivers, sloughs, and flooded islands that confounds simple modeling efforts for resolving small-scale advection and mixing processes within it. These processes determine the creation and breakdown of gradients of ecologically important scalars (e.g. salt or temperature). In light of this, field measurements and work is necessary to inform the effects of within channel transport and mixing on the region’s thermal environment, including the effects of exchanges between intersecting channels or between channels and shallow habitats. We present results of two field campaigns to assess thermal mixing processes within the Cache Slough/Liberty Island complex. For both campaigns, we deployed thermistors; conductivity, temperature, and depth (CTD) sensors; and an acoustic Doppler current profiler (ADCP). We observed the creation and breakdown of large thermal gradients, both vertically and horizontally, on a variety of time scales. Principal component analysis indicates that although much of the vertical gradients are due to local heating and cooling, fluxes of thermal gradients from adjoining channels and from shallow habitats are also important. This work leads to an improved understanding of transport and mixing in Delta channels near channel junctions and adjacent to channel/island intersections; these features are some of the dominant physical forms of the Delta.

Wahle, R. A. (1985). "The feeding ecology of Crangon franciscorum and Crangon nigricauda in San Francisco Bay, California." Journal of Crustacean Biology 5: 311-326.

Waldman, J. R., R. E. Bender, et al. (1998). "Multiple population bottlenecks and DNA diversity in populations of wild striped bass, Morone saxatilis." Fishery Bulletin 96(3): 614-620.
Striped bass, Morone saxatilis, in the Coos River, Oregon, are derived from natural colonists from San Francisco Bay, which in turn were intentionally transplanted from the Hudson River. Because of founder effects, this unusually well-documented colonization sequence should have resulted in diminished genetic variability in the penultimate and ultimate populations, which may have been further compounded in the Coos River population by subsequent drastic reductions in its abundance. To test whether these sequential bottlenecks reduced genetic diversity we surveyed both nuclear DNA (nDNA) and mitochondrial DNA (mtDNA) variation in the Coos River population and in both populations along the historical path-way that led to its founding. There was no evidence of reduced nDNA diversity among these populations at the three loci examined. However, the number of mtDNA haplotypes revealed decreased from 8 in the original Hudson River population, to 5 in the San Francisco Bay population, to only 1 in the Coos River population. This pattern of conserved nDNA diversity and reduced mtDNA diversity is consistent with a recent population bottleneck. Coos River striped bass have shown increasing levels of pathological hermaphroditism. We speculate that the reduced genetic diversity of the Coos River striped bass population may have led to a depensatory cascade involving hermaphroditism that inhibited reproduction and recruitment, followed by increased levels of inbreeding as the population declined.

Walters, R. A., R.T. Cheng, and T.J. Conomos (1985). "Time scales of circulation and mixing processes of San Francisco Bay waters." Hydrobiologia 129: 13-36.
Conceptual models for tidal period and low-frequency variations in sea level, currents, and mixing processes in the northern and southern reaches of San Francisco Bay describe the contrasting characteristics and dissimilar processes and rates in these embayments: The northern reach is a partially mixed estuary whereas the southern reach (South Bay) is a tidally oscillating lagoon with density-driven exchanges with the northern reach.

The mixed semidiurnal tides are mixtures of progressive and standing waves. The relatively simple oscillations in South Bay are nearly standing waves, with energy propagating down the channels and dispersing into the broad shoal areas. The tides of the northern reach have the general properties of a progressive wave but are altered at the constriction of the embayments and gradually change in an upstream direction to a mixture of progressive and standing waves. The spring and neap

variations of the tides are pronounced and cause fortnightly varying tidal currents that affect mixing and salinity stratification in the water column.

Wind stress on the water surface, freshwater inflow, and tidal currents interacting with the complex bay configuration are the major local forcing mechanisms creating low-frequency variations in sea level and currents. These local forcing mechanisms drive the residual flows which, with tidal diffusion, control the water-replacement rates in the estuary. In the northern reach, the longitudinal density gradient drives an estuarine circulation in the channels, and the spatial variation in tidal amplitude creates a tidally-driven residual circulation. In contrast, South Bay exhibits a balance between wind-driven circulation and tidally driven residual circulation for most of the year. During winter, however, there can be sufficient density variations to drive multilayer (2 to 3) flows in the channel of South Bay.

Mixing models (that include both diffusive and dispersive processes) are based on time scales associated with salt variations at the boundaries and those associated with the local forcing mechanisms, while the spatial scales of variations are dependent upon the configuration of the embayments. In the northern reach, where the estuarine circulation is strong, the salt flux is carried by the mean advection of the mean salt field. Where large salinity gradients are present, the tidal correlation part of the salt flux is of the same order as the advective part. Our knowledge of mixing and exchange rates in South Bay is poor. As this embayment is nearly isohaline, the salt flux is dominated entirely by the mean advection of the mean salt field. During and after peaks in river discharge, water mixing becomes more dynamic, with a strong density-driven current creating a net exchange of both water mass and salt. These exchanges are stronger during neap tides. Residence times of the water masses vary seasonally and differ between reaches. In the northern reach, residence times are on the order of days for high winter river discharge and of months for summer periods. The residence times for South Bay are fairly long (on the order of several months) during summer, and typically shorter (less than a month) during winter when density-driven exchanges occur.

Walters, R. A. and J. W. Gartner (1985). "Subtidal sea level and current variations in the northern reach of San Francisco Bay." Estuarine, Coastal, and Shelf Science 21: 17-32.
Analyses of sea level and current-meter data using digital filters and a variety of statistical methods show a variety of phenomena related to non-local coastal forcing and local tidal forcing in the northern reach of San Francisco Bay, a partially mixed estuary. Low-frequency variations in sea level are dominated by non-local variations in coastal sea level and also show a smaller influence from tidally induced fortnightly sea level variations. Low-frequency currents demonstrate a gravitational circulation which is modified by change in tidal-current speed over the spring-neap tidal cycle. Transients in gravitational circulation induce internal oscillations with periods of two to four days.

Wang, J. (1986). Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: A guide to the early life. Sacramento, Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, Technical Report 9.

Wang, J., R. T. Cheng, et al. (1997). "Seasonal sea-level variations in San Francisco Bay in response to atmospheric forcing, 1980." Estuarine, Coastal, and Shelf Science 45(1): 39-52.
The seasonal response of sea level in San Francisco Bay (SFB) to atmospheric forcing during 1980 is investigated. The relations between sea-level data from the Northern Reach, Central Bay and South Bay, and forcing by local wind stresses, sea-level pressure (SLP), runoff and the large-scale sea-level pressure field are examined in detail. The analyses show that the sea-level elevations and slopes respond to the along-shore wind stress T sub(y) at most times of the year, and to the cross-shore wind stress T sub(x) during two transition periods in spring and autumn. River runoff raises the sea-level elevation during winter. It is shown that winter precipitation in the SFB area is mainly attributed to the atmospheric circulation associated with the Aleutian Low, which transports the warm, moist air into the Bay area. A multiple linear regression model is employed to estimate the

independent contributions of barometric pressure and wind stress to adjusted sea level. These calculations have a simple dynamical interpretation which confirms the importance of along-shore wind to both sea level and north-south slope within the Bay.

Wang, W.-X., N. S. Fisher, et al. (1996). "Kinetic determinations of trace element bioaccumulation in the mussel Mytilus edulis." Marine Ecology Progress Series 140: 1-3.

Laboratory experiments employing radiotracer methodology were conducted to determine the assimilation efficiencies from ingested natural seston, the influx rates from the dissolved phase and the efflux rates of 6 trace elements (Ag, Am, Cd, Co, Se and Zn) in the mussel Mytilus edulis. A kinetic model was then employed to predict trace element concentration in mussel tissues in 2 locations for which mussel and environmental data are well described: South San Francisco Bay (California, USA) and Long Island Sound (New York, USA). Assimilation efficiencies from natural seston ranged from 5 to 18% for Ag, 0.6 to 1% for Am, 8 to 20% for Cd, 12 to 16% for Co, 28 to 34% for Se, and 32 to 41% for Zn. Differences in chlorophyll a concentration in ingested natural seston did not have significant impact on the assimilation of Am, Co, Se and Zn. The influx rate of elements from the dissolved phase increased with the dissolved concentration, conforming to Freundlich adsorption isotherms. The calculated dissolved uptake rate constant was greatest for Ag, followed by Zn > Am similar to Cd > Co > Se. The estimated absorption efficiency from the dissolved phase was 1.53% for Ag, 0.34% for Am, 0.31% for Cd, 0.11% for Co, 0.03% for Se and 0.89% for Zn. Salinity had an inverse effect on the influx rate from the dissolved phase and dissolved organic carbon concentration had no significant effect on trace element uptake. The calculated efflux rate constants for all elements ranged from 1.0 to 3.0%/d. The route of trace element uptake (food vs dissolved) and the duration of exposure to dissolved trace elements (12 h vs 6 d) did not significantly influence trace element efflux rates. A model which used the experimentally determined influx and efflux rates for each of the trace elements, following exposure from ingested food and from water, predicted concentrations of Ag, Cd, Se and Zn in mussels that were directly comparable to actual tissue concentrations independently measured in the 2 reference sites in national monitoring programs. Sensitivity analysis indicated that the total suspended solids load, which can affect mussel feeding activity, assimilation, and trace element concentration in the dissolved and particulate phases, can significantly influence metal bioaccumulation for particle-reactive elements such as Ag and Am. For all metals, concentrations in mussels are proportionately related to total metal load in the water column and their assimilation efficiency from ingested particles. Further, the model predicted that over 96% of Se in mussels is obtained from ingested food, under conditions typical of coastal waters. For Ag, Am, Cd, Co and Zn, the relative contribution from the dissolved phase decreases significantly with increasing trace element partition coefficients for suspended particles and the assimilation efficiency in mussels of ingested trace elements; values range between 33 and 67% for Ag, 5 and 17% for Am, 47 and 82% for Cd, 4 and 30% for Co, and 17 and 51% for Zn.

Wankel, S. D., C. Kendall, et al. (2006). "Nitrogen sources and cycling in the San Francisco Bay Estuary: A nitrate dual isotopic composition approach." Limnology and Oceanography 51(4): 1654-1664.

We used the dual isotopic composition of nitrate (delta N-15 and delta O-18) within the estuarine system of San Francisco (SF) Bay, California, to explore the utility of this approach for tracing sources and cycling of nitrate (NO3-). Surface water samples from 49 sites within the estuary were sampled during July-August 2004. Spatial variability in the isotopic composition suggests that there are multiple sources of nitrate to the bay ecosystem including seawater, several rivers and creeks, and sewage effluent. The spatial distribution of nitrate from these sources, is heavily modulated by the hydrodynamics of the estuary. Mixing along the estuarine salinity gradient is the main control on the spatial variations in isotopic composition of nitrate within the northern arm of SF Bay. However, the nitrate isotopic composition in the southern arm of SF Bay exhibited a combination of source mixing and phytoplankton drawdown due mostly to the long residence time during the summer study period. Very low delta O-18(NO3) values (as low as -5.0 parts per

thousand) at the Sacramento-San Joaquin River delta region give rise to a wide range of delta O-18(NO3) values in the SF Bay system. The range in delta O-18(NO3) values is more than twice that of delta N-15(NO3), suggesting that delta 18O(NO3) is an even more sensitive tool for tracing nitrate sources and cycling than 615N(NO3).

Waples, R. S., D. J. Teel, et al. (2004). "Life-History Divergence In Chinook Salmon: Historic Contingency And Parallel Evolution." Evolution 58(2): 386-403.
By jointly considering patterns of genetic and life-history diversity in over 100 populations of Chinook salmon from California to British Columbia, we demonstrate the importance of two different mechanisms for life-history evolution. Mapping adult run timing (the life-history trait most commonly used to characterize salmon populations) onto a tree based on the genetic data shows that the same run-time phenotypes exist in many different genetic lineages. In a hierarchical gene diversity analysis, differences among major geographic and ecological provinces explained the majority (62%) of the overall G ST, whereas run-time differences explained only 10%. Collectively, these results indicate that run-timing diversity has developed independently by a process of parallel evolution in many different coastal areas. However, genetic differences between coastal populations with different run timing from the same basin are very modest (G ST < 0.02), indicating that evolutionary divergence of this trait linked to reproductive isolation has not led to parallel speciation, probably because of ongoing gene flow. A strikingly different pattern is seen in the interior Columbia River Basin, where run timing and other correlated life-history traits map cleanly onto two divergent genetic lineages (G ST similar to 0.15), indicating that some patterns of life-history diversity have a much older origin. Indeed, genetic data indicate that in the interior Columbia Basin, the two divergent lineages behave essentially as separate biological species, showing little evidence of genetic contact in spite of the fact that they comigrate through large areas of the river and ocean and in some locations spawn in nearly adjacent areas.

Warner, G. (1991). Remember the San Joaquin. California's salmon and steelhead: The struggle to restore an imperiled resource. A. Lufkin. Berkeley, CA, and Oxford, England, UK, University of California Press: 61-70.

Warner, J., D.H. Schoellhamer, J.R. Burau , and G. Schladow (2002). "Effects of tidal current phase at the junction of two straits." Continental Shelf Research 22: 14.
Estuaries typically have a monotonic increase in salinity from freshwater at the head of the estuary to ocean water at the mouth, creating a consistent direction for the longitudinal baroclinic pressure gradient. However, Mare Island Strait in San Francisco Bay has a local salinity minimum created by the phasing of the currents at the junction of Mare Island and Carquinez Straits. The salinity minimum creates converging baroclinic pressure gradients in Mare Island Strait. Equipment was deployed at four stations in the straits for 6 months from September 1997 to March 1998 to measure tidal variability of velocity, conductivity, temperature, depth, and suspended sediment concentration. Analysis of the measured time series shows that on a tidal time scale in Mare Island Strait, the landward and seaward baroclinic pressure gradients in the local salinity minimum interact with the barotropic gradient, creating regions of enhanced shear in the water column during the flood and reduced shear during the ebb. On a tidally averaged time scale, baroclinic pressure gradients converge on the tidally averaged salinity minimum and drive a converging near-bed and diverging surface current circulation pattern, forming a “baroclinic convergence zone” in Mare Island Strait. Historically large sedimentation rates in this area are attributed to the convergence zone.

Warner, J. C., D. H. Schoellhamer, et al. (1996). A sediment transport pathway in the back of a nearly semienclosed subembayment of San Francisco Bay, California. Environmental and Coastal Hydraulics: Protecting the Aquatic Habitat. Volume 2. S. S. Y. Wang and T. Carstens. nowhere, ASCE: 1096-1101.

Warner, J. C., D. H. Schoellhamer, et al. (2006). "Flow Convergence Caused by a Salinity Minimum in a Tidal Channel " San Francisco Estuary and Watershed Science 4(3): Article 1.

Residence times of dissolved substances and sedimentation rates in tidal channels are affected by residual (tidally averaged) circulation patterns. One influence on these circulation patterns is the longitudinal density gradient. In most estuaries the longitudinal density gradient typically maintains a constant direction. However, a junction of tidal channels can create a local reversal (change in sign) of the density gradient. This can occur due to a difference in the phase of tidal currents in each channel. In San Francisco Bay, the phasing of the currents at the junction of Mare Island Strait and Carquinez Strait produces a local salinity minimum in Mare Island Strait. At the location of a local salinity minimum the longitudinal density gradient reverses direction. This paper presents four numerical models that were used to investigate the circulation caused by the salinity minimum: (1) A simple one-dimensional (1D) finite difference model demonstrates that a local salinity minimum is advected into Mare Island Strait from the junction with Carquinez Strait during flood tide. (2) A three-dimensional (3D) hydrodynamic finite element model is used to compute the tidally averaged circulation in a channel that contains a salinity minimum (a change in the sign of the longitudinal density gradient) and compares that to a channel that contains a longitudinal density gradient in a constant direction. The tidally averaged circulation produced by the salinity minimum is characterized by converging flow at the bed and diverging flow at the surface, whereas the circulation produced by the constant direction gradient is characterized by converging flow at the bed and downstream surface currents. These velocity fields are used to drive both a particle tracking and a sediment transport model. (3) A particle tracking model demonstrates a 30 percent increase in the residence time of neutrally buoyant particles transported through the salinity minimum, as compared to transport through a constant direction density gradient. (4) A sediment transport model demonstrates increased deposition at the near-bed null point of the salinity minimum, as compared to the constant direction gradient null point. These results are corroborated by historically noted large sedimentation rates and a local maximum of selenium accumulation in clams at the null point in Mare Island Strait.

Warner, J. C., D. H. Schoellhamer, et al. (2004). "Floodtide pulses after low tides in shallow subembayments adjacent to deep channels." Estuarine, Coastal and Shelf Science 60(2): 213-228.
In shallow waters surface gravity waves (tides) propagate with a speed proportional to the square root of water depth (c=g(h+ eta)). As the ratio of free surface displacement to mean depth (eta /h) approaches unity the wave will travel noticeably faster at high tide than at low tide, creating asymmetries in the tidal form. This physical process is explained analytically by the increased significance of friction and the nonlinear terms in the continuity and momentum equations. In a tidal system comprising a shallow bay adjacent to a deeper channel, tidal asymmetries will be more prevalent in the shallow bay. Thus strong barotropic gradients can be generated between the two, producing rapid accelerations of currents into the bay (relative to other bay tidal processes) and create a maximum peak in the flood tide that we describe as a floodtide pulse. These floodtide pulses can promote a landward flux of suspended-sediment into the bay. In Grizzly Bay (part of northern San Francisco Bay, USA), field observations verify the occurrence of floodtide pulses during the lowest low tides of the year. No pulses were observed in neighboring Honker Bay, which has an average depth similar to 30cm greater than Grizzly Bay. Numerical simulations of northern San Francisco Bay using realistic bathymetry demonstrated that floodtide pulses occurred in Grizzly Bay but not in Honker Bay, consistent with the observations. Both observations and numerical simulations show that floodtide pulses promote a landward flux of sediment into Grizzly Bay. Numerical simulations of an idealized bay-channel system quantify the importance of mean depth and friction in creating these floodtide pulses.

Warner, J. C., D. H. Schoellhamer, et al. (2003). "Tidal truncation and barotropic convergence in a channel network tidally driven from opposing entrances." Estuarine, Coastal and Shelf Science 56(629-639).
Residual circulation patterns in a channel network that is tidally driven from entrances on opposite sides are controlled by the temporal phasing and spatial asymmetry of the two forcing tides. The Napa/Sonoma Marsh Complex in San Francisco Bay, CA, is such a system. A sill on the west entrance to the system prevents a

complete tidal range at spring tides that results in tidal truncation of water levels. Tidal truncation does not occur on the east side but asymmetries develop due to friction and off-channel wetland storage. The east and west asymmetric tides meet in the middle to produce a barotropic convergence zone that controls the transport of water and sediment. During spring tides, tidally averaged water-surface elevations are higher on the truncated west side. This creates tidally averaged fluxes of water and sediment to the east. During neap tides, the water levels are not truncated and the propagation speed of the tides controls residual circulation, creating a tidally averaged flux in the opposite direction.

Warnock, N., G. W. Page, et al. (2002). "Management and conservation of San Francisco bay salt ponds: Effects of pond salinity, area, tide, and season on Pacific flyway waterbirds."

Throughout the world, coastal salt ponds provide habitat for large numbers and diversities of waterbirds. San Francisco Bay contains the most important coastal salt pond complexes for waterbirds in the United States, supporting more than a million waterbirds through the year. As an initial step in attempting to understand how the anticipated conversion of salt ponds to tidal marsh might affect the Bay's bird populations, the number of birds using salt ponds on high and low tides was counted during the winter months of 1999/00 and 2000/01. Behavior and habitat use of birds in these ponds were assessed, and the effects of tide cycle, pond salinity, and pond area on bird use were examined. We recorded 75 species of waterbirds in surveys of salt ponds in the South Bay from September 1999 to February 2001 totaling over a million bird use days on high tide. Shorebirds and dabbling ducks were the most abundant groups of birds using the salt ponds. Waterbird numbers and diversity were significantly affected by the salinity of ponds in a non-linear fashion with lower numbers and diversity on the highest salinity ponds. With the exception of ducks and Eared Grebe (Podiceps nigricollis), tide height at the Bay significantly affected bird numbers in the salt ponds with ponds at high tides having higher numbers of birds than the same ponds on low tides, Considerable numbers of birds fed in the salt ponds on high and low tides, although this varied greatly by species. Habitat use varied by tide. Management recommendations include maintaining ponds of varying salinities and depths. Restoring salt ponds to tidal marsh should proceed with caution to avoid loss of waterbird diversity and numbers in San Francisco Bay.

Warnock, S. E. and J. Y. Takekawa (1995). "Habitat preferences of wintering shorebirds in a temporally changing environment: Western sandpipers in the San Francisco Bay estuary." Auk 112(4): 920-930.

We examined habitat preferences of 106 radio-marked Western Sandpipers (Calidris mauri) in the San Francisco Bay estuary during winter and spring at two scales: comparing proportions of habitats in their home range with habitats available in the study area (second-order selection), and comparing proportions of radio locations in different habitats with their availability in the home range (third-order selection). Daily and seasonal habitat preferences differed significantly as habitat availability changed temporally. Under second-order selection, Western Sandpipers preferred tidal sloughs and mud flats on winter low tides, and salt-pond levees at high tides. They preferred salt-pond levees and mud flats at low tides, and salt-pond levees at high tides under third-order selection. During the spring, they preferred habitats were drained and tidal salt ponds, and seasonal wetlands at high tide. At low tide, their preferred habitats were tidal sloughs and tidal salt ponds. Salt-marsh plains were the least preferred habitats during both seasons. Adults were more selective than juveniles in use of low tide habitats, but salt-pond levees were the most preferred habitats for both. Habitat preferences varied considerably when different estimates of habitat availability and use were used. If mud-flat habitats were measured as linear foraging areas along the tide line, the preference for those habitats increased from second to first. When second-order selection was estimated from radio locations rather than home ranges, the resulting composition was similar to third-order selection. Our results suggest that regional conservation plans that restore salt marshes for the benefit of endangered species must consider the effects of losing artificial salt-pond habitats, which are locally important for sandpipers.

Washburn, B., and K. Yancey (2010). Analysis of impervious cover: Development of a

set of impervious surface coefficients for California's land uses. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
A set of impervious surface coefficients (ISC) have been developed that reflect California’s land use categories (LUC). The ISCs were developed for commerical and residential LUCs as well as 3 types of roads. Data from Sacramento, Santa Cruz, and Irvine was used to represent land uses in the Central Valley, the Coast, and Southern California. Impervious cover was digitized off of high resolution aerial photoraphs using a stratified (by land use category) random sample design. Sufficient sites were selected to achieve 90% confidence with +/- 10% accuracy. ISCs for 11 non-residential categories were calculated. For residential land use, a regression equation was developed that identified % impervious cover based on the density of housing units (dwelling units/acre). This equation will support analysis of residential land use from rural residential up to high density development (50 du/acre). Three coefficients for roads; for rural, urban/suburban, and highways, were also calculated. The coefficients can be used in watershed assessments, stormwater runoff calculations, and for improved land use planning. Examples of each will be presented.

Washburn, B., W. Wieland, L. Allen, K. Pulsipher, E. Berntsen, and C. Bowles (2010). Estimating channel vulnerability to erosion. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Turbidity levels in Secret Ravine, a small tributary of Dry Creek (Sacramento and Placer counties) exceed standards known to support reproduction of salmonids and viability of young fish. To better understand the spatial variability and the causes of this problem, we estimated erodibility of the creek using the Channel Vulnerability Calculator, a excel-based tool that estimates the relative erodibility ratio (RER), a measure of the erosive forces on the bed and bank relative to resistive forces. A RER greater than 1 suggests that erosive forces dominate. In Secret Ravine, RER values ranged from .83 to 30.23, suggesting that erosion is a dominant factor in this urbanizating watershed. To validate the use of the Calculator, we are currently testing it at an additional 10 sites in the larger Dry Creek watershed as well as comparing results to those obtained using a rapid geomorphic assessment protocol. Since the RER is most sensitive to the dominant substrate in the channel, bankfull height, and gradient, efforts are also focusing on determining the most reliable way to collect these measurements. The Calculator has broad use related to bioassessment and physical habitat data (PHAB)analysis. Much of the data needed is currently being collected as part of the SWAMP’s PHAB protocol. Preliminary analysis of the RERs shows they are correlated with metrics of benthic macroinvertebrate abundance and diversity. Erodibility ratios could serve as a useful indicator of stream condition which could help shape watershed management and policy.

Watry, C., J. Anderson, J. Montgomery, B. Beckett, C. Laskodi, P. Skvorc, and J. Merz (2010). Biological pattern recognition and morphometrics to passively ‘mark’ fish and improve data collection quality. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Traditional tagging and marking techniques typically involve invasive procedures and are limited by tag or mark life, and the ability to identify individual fish. Assumptions about tag and mark retention are also required. We demonstrate a non-invasive method of using natural spot patterns to uniquely identify individuals from a population of steelhead trout Oncorhynchus mykiss. The natural-tag (TNT) is a technique that uses digital images of the dorsum of the head to isolate cephalic spots from a discreet area of interest for biological pattern recognition, similar to human fingerprints; and, full lateral views for analyzing morphometrics. The required imagery can be collected quickly without using anesthetic, thus minimizing handling stress and eliminating invasive procedures. Spots isolated in the area of interest generate a pattern that is unique and recognizable for the life of the individual. Computer generated length measurements are extremely precise and made using morphometrics; likewise, weight can be determined with similar accuracy for populations where length-weight relationships have been developed. Potential applications for using morphometrics to discriminate

ecological traits include: species or subspecies; race; and, gender. This method has many implications for fisheries management and has the potential to provide scientists with new tools that may greatly improve the quality, reliability, and cost-effectiveness of data collection.

Watry, C., A. Gray, and J. Merz (2010). Conceptual approach for process-based restoration in regulated Central Valley rivers. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Regulated flow management in rivers throughout California’s Central Valley has altered ecosystem processes necessary for maintaining critical habitats for native salmonids. Primary impacts include a general reduction in channel maintenance flows and concurrent loss of coarse sediment recruitment. Over time, this primary impact has affected structural processes leading to the following channel responses: scour; over-deepening; loss of gradient; and, reduced sediment mobilization. The cumulative effects of these changing structural processes has increased bank and bed armoring, and contributed to vegetative encroachment resulting in disconnection of the floodplain from the active channel. Additional physical habitat responses include slower velocities and increased fine sediments, further reducing the availability of appropriate substrate quantity and quality to support productive salmonid populations. Moreover, instream and hyporheic water quality is subsequently degraded. All of these altered conditions have negatively affected functional processes by decreasing habitat heterogeneity generally reducing spawning use, embryo production, juvenile survival, and macroinvertebrate community structure and production. Understanding the complex interactions and factors that contribute to habitat degradation is important to identifying the most appropriate management actions for native salmonids. We present a conceptual approach for process-based restoration to recover ecosystem functions while working within current and future management constraints. First, we describe a method for identifying ecological relevant flows (ERF) for important life history periods. Then, we explain how to assess current conditions to identify targeted restoration actions that confer the greatest ecological benefits to critical habitats by enhancing the conditions that promote fish production and survival. Finally, we discuss the importance of developing long-term management plans to ensure continued project success.

Watson, E. B. (2008). "Marsh expansion at Calaveras Point Marsh, South San Francisco Bay, California." Estuarine, Coastal and Shelf Science 78(4): 593-602.

Studies of shoreline progradation along low-energy vegetated shorelines have been limited, as these environments are generally experiencing erosion rather than deposition, with extreme erosion rates frequently found. This study examined yearly changes along a vegetated shoreline at Calaveras Point Marsh, South San Francisco Bay, California, using aerial photography, to determine the roles of climatic, watershed, and coastal process in driving shoreline changes. In addition, sediment accumulation was monitored on a yearly basis at 48 locations across the marsh to determine the role of geomorphic factors in promoting accumulation. Calaveras Point Marsh was found to have expanded from 49.26 +/- 5.2 to 165.7 +/- 4.7 ha between 1975 and 2005. Although the rate of marsh expansion was not positively correlated with yearly variability in precipitation, local streamflow, delta outflow, water level observations, population growth, or ENSO indices, marsh growth was greater during years of higher than average temperatures. Warmer temperatures may have promoted the recruitment and growth of Spartina foliosa, a C-4 grass known to be highly responsive to temperature. Other factors, such as the formation of a coastal barrier, a recent change in the location of the mouth of the Guadalupe River, and channel readjustment in response to diking are credited with driving the bulk of the marsh expansion. Sediment accumulation was found to be high closest to channels and to the shoreline, at low elevations and in recently vegetated marsh. Globally, the pace of sea level rise exerts the primary control on wetland development and persistence. However, at local geographic scales, factors such as tectonic events, modifications to natural sediment transport pathways or land use changes may overwhelm the effects of regional sea level rise, and allow for wetlands to develop, expand and persist despite rapid sea level rise. (C) 2008 Elsevier Ltd. All rights reserved.

Watson, E. B. and R. Byrne (2009). "Abundance and diversity of tidal marsh plants along the salinity gradient of the San Francisco Estuary: implications for global change ecology." Plant Ecology 205(1): 113-128.
        From 2003 through 2005, tidal marsh plant species diversity and abundance on historically surveyed vegetation transects along the salinity gradient of the San Francisco Estuary were investigated to establish empirical relationships between plant distributions and environmental conditions, and furthermore to examine and predict past and future plant distribution changes. This study suggests that for most species, salinity is the primary control on plant distribution. Thus, ongoing changes in estuarine conditions (increasing sea level and salinity) are resulting in a complex mix of plant distribution changes. On the low marsh, where sediment salinity is similar to that of ambient water, halophytic species are replacing salt-intolerant taxa. However, on marsh plains, where increased tidal flooding is moderating high salinity (concentrated by evaporation), halophytic "high marsh" species are being replaced by salt-intolerant "low marsh" taxa. Thus, future changes in plant distributions will hinge on whether marsh sediment accumulation keeps pace with sea level rise.

Watters, D. L., H. M. Brown, et al. (2004). Pacific Herring Spawning Grounds in San Francisco Bay: 1973-2000. Early Life History of Fishes in the San Francisco Estuary and Watershed. F. Feyrer, L. R. Brown, R. L. Brown and J. J. Orsi. Bethesda MD, American Fisheries Society: 3-14.
        San Francisco Bay provides spawning and rearing habitat for California's largest population of Pacific herring Clupea pallasi. This population provides a food source for other species and supports a valuable fishery for Pacific herring roe. Since the inception of the roe fishery in 1973, the California Department of Fish and Game has conducted annual surveys of spawning in San Francisco Bay as part of an ongoing assessment of population status and management of the fishery. The purpose of this paper is to document (1) regions of San Francisco Bay used by Pacific herring as spawning grounds over time, and (2) time periods in which spawning took place. Spawn data were analyzed by geographic region in the bay and by month for the period 1973-2000. During this period, we documented 269 spawning events from Point San Pablo south to Redwood City. Estimates of spawning adult biomass (fish that were not harvested by the fishery) ranged from 80,813 metric tons in 1981-1982 to 3,199 metric tons in 1997-1998 (mean = 34,688 plus or minus 19,325 SD). January was the peak spawning month, followed by December and February; small variations in this pattern occurred during some years. Overall, the majority of spawning took place in the north-central bay region (Point Bonita to Richmond-San Rafael Bridge, Angel Island, Point San Pablo, Berkeley flats; 55%) and the San Francisco region (Golden Gate Bridge to Candlestick Point; 34%), although it alternated between these two regions over time. In some years, considerable spawning took place in the Oakland-Alameda region (San Francisco-Oakland Bay Bridge to Bay Farm Island). The largest spawns and peak periods of spawning may not contribute most toward the next generation of Pacific herring, due to differential mortality within the season. For this reason, all regions documented in this study are important spawning grounds for Pacific herring from November through March each year. A number of recent studies have furthered our understanding of Pacific herring early life history and the forces that drive year-class formation in San Francisco Bay. However, studies are especially needed that will improve our ability to adequately address the potential impacts of human activities on Pacific herring in this highly urbanized estuary.

Weber, E. D. and K. D. Fausch (2004). "Abundance and Size Distribution of Ocean-Type Juvenile Chinook Salmon in the Upper Sacramento River Margin before and after Hatchery Releases." North American Journal of Fisheries Management 24(4): 1447-1455.
        If hatchery-reared salmon delay emigration after release, they may compete with wild salmon in freshwater rearing habitat. We measured the densities and size distributions of ocean-type juvenile Chinook salmon Oncorhynchus tshawytscha in two rearing areas downstream of a hatchery in the Sacramento River, California, before, during, and after two large releases in both 2001 and 2002. Densities of juvenile salmon followed a unimodal trend through time, peaking at about 0.5-1.5 fish/m super(2) during late March or early April but declining by the time hatchery fish were released in mid to late April. Hatchery releases did not increase densities

above the underlying trend, except after one release at one site. Density increased by 0.83 fish/m super(2) (SE, 0.30 fish/m super(2)) after this release but returned to the baseline level within 3 d. Although hatchery fish were much larger than most wild fish, the mean size of fish captured did not increase appreciably after hatchery releases, even after the release when density increased. These data suggest that the strategy of delaying hatchery releases until many hatchery fish were smoltifying and many wild fish have emigrated was relatively effective in reducing potential interactions in freshwater rearing areas of the stream margin in the upper river.

Weber, E. D. and K. D. Fausch (2005). "Competition between Hatchery-Reared and Wild Juvenile Chinook Salmon in Enclosures in the Sacramento River, California." Transactions of the American Fisheries Society 134(1): 44-58.
We conducted two types of experiments in the upper Sacramento River, California, to test the effects of hatchery-reared juvenile Chinook salmon Oncorhynchus tshawytscha on the emigration, growth, and survival of their wild counterparts. In 3 years of displacement experiments, emigration rates from 8-m super(2) enclosures into downstream traps were similar between control enclosures that contained 40 wild fish and treatment enclosures to which 33 or 40 hatchery fish were also added. The mean number of wild fish in enclosures at the end of experiments differed by less than one fish between treatments and controls during all 3 years, indicating that hatchery fish prompted few wild fish to emigrate. In 2 years of competition experiments wherein fish could not emigrate, the enclosures contained wild fish (40 fish), wild fish plus hatchery fish (40 wild fish plus 33 or 40 hatchery fish), or wild fish at the same total density as the treatment with wild plus hatchery fish (73 or 80 wild fish). During 2001, survival and specific growth rates of wild fish were similar among treatments, probably because resources were not limiting. During 2002, survival was similar among treatments, but the mean specific growth rate was 0.008 g/d higher in the treatment with 40 wild fish than in the treatment with wild plus hatchery fish (95% confidence interval [CI], 0.005-0.011 g/d). These data indicated a negative effect on wild fish growth of adding hatchery fish. The specific growth rate in the high-density wild fish treatment was intermediate and 0.003 g/d higher than in the treatment with hatchery fish (95% CI, -0.0005 to +0.006 g/d), providing some evidence that hatchery fish had a greater negative effect on wild fish growth than an equal density of wild fish did.

Weber, P. K., I. D. Hutcheon, et al. (2002). "Otolith sulfur isotope method to reconstruct salmon (Oncorhynchus tshawytscha) life history." Canadian Journal of Fisheries and Aquatic Sciences 59(4): 587-591.
A new ion microprobe method to reconstruct aspects of fish life history is reported based on sulfur isotopes (super(34)S/ super(32)S, expressed as delta super(34)S). Selected hatchery raised and naturally spawned juvenile chinook salmon (Oncorhynchus tshawytscha) are shown to have a 12.96 plus or minus 0.27% (mean plus or minus 2 standard errors) difference in muscle delta super(34)S values, corresponding to delta super(34)S differences between the hatchery and freshwater diets. Isotopic microanalyses of otoliths demonstrate that this 13% difference is preserved in the otoliths. The otolith delta super(34)S record is interpreted to be a chronology of dietary delta super(34)S, with approximately one-week temporal resolution, preserved in these banded calcium carbonate structures. Potential applications of this method include identifying hatchery raised fish and reconstructing nutrition sources, migration, and other aspects of fish life history.

Weed, D. L. (2005). "Weight of Evidence: A Review of Concept and Methods." Risk Analysis 25(6): 13.
“Weight of evidence” (WOE) is a common term in the published scientific and policy-making
literature, most often seen in the context of risk assessment (RA). Its definition, however, is
unclear. A systematic review of the scientific literature was undertaken to characterize the
concept. For the years 1994 through 2004, PubMed was searched for publications in which

“weight of evidence” appeared in the abstract and/or title. Of the 276 papers that met these
criteria, 92 were selected for review: 71 papers published in 2003 and 2004 (WOE appeared
in abstract/title) and 21 from 1994 through 2002 (WOE appeared in title). WOE has three
characteristic uses in this literature: (1) metaphorical, where WOE refers to a collection of
studies or to an unspecified methodological approach; (2) methodological, where WOE points
to established interpretative methodologies (e.g., systematic narrative review, meta-analysis,
causal criteria, and/or quality criteria for toxicological studies) or where WOE means that
“all” rather than some subset of the evidence is examined, or rarely, where WOE points to
methods using quantitative weights for evidence; and (3) theoretical, where WOE serves as
a label for a conceptual framework. Several problems are identified: the frequent lack of
definition of the term “weight of evidence,” multiple uses of the term and a lack of consensus
about its meaning, and the many different kinds of weights, both qualitative and quantitative,
which can be used in RA. A practical recommendation emerges: the WOE concept and its
associated methods should be fully described when used. A research agenda should examine
the advantages of quantitative versus qualitative weighting schemes, how best to improve
existing methods, and how best to combine those methods (e.g., epidemiology’s causal criteria
with toxicology’s quality criteria).

Weiskel, H., C. Janousek, and E. Grosholz (2010). Nutrient loading and benthic native-invasive species dynamics. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The effects of nutrient loading on the success of biological invasions is best understood in terrestrial systems, where studies have generally shown that increased nutrients facilitate the spread of invasive plants. To date, these relationships have remained largely unexamined in marine systems and at higher trophic levels. We conducted studies to examine the effects of interactions between nutrient loading and invasion by the invasive mud snail, Ilyanassa obsoleta, on the native snail Cerithidea californica, in San Francisco Bay. We experimentally manipulated densities of Cerithidea and Ilyanassa as well as nutrient levels at two tidal elevations to investigate the role of nutrients in invasion success in this system. Results indicate that nutrient additions increased microalgal (diatom) biomass at both tidal elevations. The native snail grew significantly more than the invasive snail on the higher, vegetated marsh, where it is generally found. Similarly, the invader grew significantly more than the native on the lower, unvegetated mudflat, where its densities are generally higher. Nutrients increased growth in both species but did not alter this “home team” habitat advantage. However, nutrients did significantly increase growth of the native on the marsh compared with the mudflat. Without nutrients, Cerithidea growth on the marsh was not significantly greater than on the mudflat, suggesting that nutrients provide a refuge for the native in this habitat. While nutrients consistently benefited Cerithidea with regard to growth, they harmed Ilyanassa with regard to mortality. Overall, nutrients significantly increased mortality of the invader but did not affect native mortality. In summary, these results indicate that nutrients in soft sediment benthic systems can play an important quantitative role in determining invasion success at higher trophic levels by affecting competitive dynamics between native and invasive species but their qualitative impact is context-dependent. Nutrient control should be a critical element of Bay-Delta management efforts.

Werner, I., and J.T. Hollibaugh (1993). "Potamocorbula amurensis (Mollusca, Pelecyopoda): Comparison of clearance rates and assimilation efficiencies for phytoplankton and bacterioplankton." Limnology and Oceanography 38(5): 26.

This study compared clearance and assimilation of natural bacterioplankton (< 1.2 pm) and cultured phytoplankton by an Asian bivalve, Potamocorbula amurensis. The average clearance rate for bacterioplankton was 45 ml h-1 clam-1 and was independent of the size (shell length, wet wt including shell, or dry tissue wt) of the clam. The clearance rate for phytoplankton is given by f = 162 + 166 x WW or f = -40 + 199 x L where f, WW, and L are clearance rate (ml h-1), wet weight including shell (g), and shell length (cm). Bacteria were readily assimilated by P. amurensis. Gross assimilation was 73% after 49 h compared to 90% for Isochrysis galbana. Net assimilation was 45 and 53% for bacterioplankton and I. galbana, respectively. Bacterial carbon appeared to be respired faster than algal carbon. As seen in other bivalves, feces production increased and assimilation efficiency decreased at higher food concentrations. At the mean bacterioplankton and phytoplankton standing stocks found in northern San Francisco Bay, bacteria supplied 13 and 16% of the sum of bacteria and phytoplankton C and N, respectively, consumed by a 1-cm P. amurensis. We calculate that a 1-cm clam could double its C biomass in 221 d by feeding on bacterioplankton and in 26 d by feeding on phytoplankton.

Werner, I., L.A. Deanovic, V. Conner, V. de Vlaming, H.C. Bailey, and D.E. Hinton (2000). "Insecticide-caused toxicity to Ceriodaphnia dubia (Cladocera) in the Sacramento-San Joaquin River Delta, California, USA." Environmental Toxicology and Chemistry 19(1): 13.

In recent years, populations of resident aquatic species in California's Sacramento-San Joaquin Delta, USA, have declined appreciably in numbers. The cause of these declines is not known, but has been attributed to a number of factors including water diversions, loss of habitat, introduced exotic organisms, and toxic compounds. To detect and characterize the spatial extent, severity, frequency, and causes of potential toxicity caused by anthropogenic pollutants, a monitoring study was conducted over a period of two years (1993-1995). Sites were monitored on a monthly basis using the standardized U.S. Environmental Protection Agency freshwater toxicity test with the zooplankton species Ceriodaphnia dubia. Twenty-four sites were sampled in 1993 to 1994. During the 1994 to 1995 sampling season, the number of sampling sites was restricted to 20, with special emphasis placed on back sloughs, delta island agricultural drains, and main-stem river sites. Significant mortality or reproductive toxicity in C. dubia was detected in 9.8% of 400 water samples tested. Ecologically important back sloughs had the largest percentage of toxic samples. Of 71 and 103 samples collected from back sloughs during 1993 to 1994 and 1994 to 1995, respectively, 14.1% and 19.6% were toxic. To determine the causative chemical(s), toxicity identification evaluations (TIEs) were conducted on 23 toxic samples. These included eight follow-up samples taken to determine whether toxicity at the respective site persisted. Organophosphate (chlorpyrifos, diazinon, malathion) and carbamate (carbofuran, carbaryl) pesticides were identified as primary toxicants. Chlorpyrifos was present at toxic concentrations in 87% of samples tested by TIE. Analysis of data from the follow-up samples suggested that toxicity may have persisted over periods of several days to weeks.

Werner, I. (2004). "The influence of salinity on the heat-shock protein response of Potamocorbula amurensis (Bivalvia)." Marine Environmental Research 58(2-5): 803-807.

For biomarkers to be useful in assessing anthropogenic impacts in field studies involving aquatic organisms, they should not be affected by naturally occurring changes in environmental parameters such as salinity. This is especially important in estuarine environments and for relatively unspecific biomarkers like heat-shock proteins (hsps, stress proteins). In this study, the heat-shock protein response was measured in the euryhaline clam, Potamocorbula amurensis, after exposure to a range of salinities reflecting normal and extreme environmental conditions in Northern San Francisco Bay, California. The ability to raise cellular hsp70 levels in response to heat-shock was significantly impaired in P. amurensis collected from a low (0.5 ppt) salinity field site, and after 14 day exposure to low salinity in the laboratory.

Werner, I., L. A. Deanovic, et al. (2010). "Monitoring acute and chronic water column toxicity in the Northern Sacramento-San Joaquin Estuary, California, USA, using the euryhaline amphipod, Hyalella azteca: 2006 to 2007." Environmental Toxicology and Chemistry 29(10): 2190-2199.
After the significant population decline of several pelagic fish species in the Northern Sacramento–San Joaquin (SSJ) Estuary (CA, USA) in 2002, a study was performed to monitor water column toxicity using the amphipod Hyalella azteca. From January 1, 2006 to December 31, 2007, water samples were collected biweekly from 15 to 16 sites located in large delta channels and main-stem rivers, selected based on prevalent distribution patterns of fish species of concern. Ten-day laboratory tests with H. azteca survival and relative growth as toxicity endpoints were conducted. The enzyme inhibitor piperonyl butoxide ([PBO], 25 µg/L) was added to synergize or antagonize pyrethroid or organophosphate (OP) insecticide toxicity, respectively. Significant amphipod mortality was observed in 5.6% of ambient samples. Addition of PBO significantly changed survival or growth in 1.1% and 10.1% of ambient samples, respectively. Sites in the Lower Sacramento River had the largest number of acutely toxic samples, high occurrence of PBO effects on amphipod growth (along with sites in the South Delta), and the highest total ammonia/ammonium concentrations (0.28 ± 0.15 mg/L). Ammonia/ammonium, or contaminants occurring in mixture with these, likely contributed to the observed toxicity. Pyrethroid insecticides were detected at potentially toxic concentrations. Overall, results of this study identified specific areas and contaminants of concern and showed that water in the Northern SSJ Estuary was at times acutely toxic to sensitive invertebrates. Environ.

Werner, I. and D. E. Hinton (2000). "Spatial profiles of HSP70 proteins in Asian clam (Potamocorbula amurensis) in northern San Fransisco Bay may be linked to natural rather than anthropogenic stressors." Marine environmental research 50(1-5): 379-384.
Multi-year investigations in northern San Francisco Bay by United States Geological Survey have linked reduced condition indices in populations of Asian clam (Potamocorbula amurensis) with elevated cadmium tissue concentrations. Our study seeks to determine whether levels of hsp70 proteins in P. amurensis can be correlated with these findings, and/or are related to histopathologic alterations and concentrations of metallothionein-like proteins. Here we present our results on stress proteins in clams collected monthly from four field stations between July 1996 and January 1998. In addition, animals were exposed in the laboratory to a range of salinities. Stress proteins were analyzed by Western blotting using monoclonal antibodies. Hsp70 protein levels in field-collected clams were significantly higher at the seaward (high salinity/low cadmium) stations (12.5, 8.1) than at the landward (low salinity/high cadmium) stations (6.1, 4.1). Laboratory studies showed that clams exposed to 0.1 ppt salinity had markedly lower hsp70 levels than clams exposed to higher salinities. In view of our previous laboratory studies showing that cadmium induces hsp70 in P. amurensis, our present results indicate that reduced hsp70 protein levels in field-collected clams may be linked to salinity effects rather than cadmium tissue concentrations.

Werner, I., K. F. Kline, et al. (1996). "Stress Proteins in Amphipods as Biomarkers of Sediment Pollution in San Francisco Bay. IEP (Interagency Ecological Program for the Sacramento-San Joaquin Estuary) Technical Report 48."

Werner, I., K. F. Kline, et al. (1998). "Stress protein expression in Ampelisca abdita (Amphipoda) exposed to sediments from San Francisco Bay." Marine Environmental Research 45: 417-430.
Stress proteins (heat shock proteins, hsps) form part of the cellular protein repair system, and are induced by a wide variety of stressors. To determine their suitability as tools for assessing sublethal sediment toxicity, we measured levels of members of the stress protein families hsp60 and hsp70 in benthic estuarine amphipods (Ampelisca abdita) exposed to sediments from 23 different sampling sites in San Francisco Bay for 10d. Concentrations of sediment-associated xenobiotics were determined. Per cent survival was recorded and surviving animals were analysed for stress proteins using western blotting techniques. An inverse

correlation (r super(2)=0.44) was seen between amphipod survival and hsp64 levels, and hsp64 levels were positively correlated with concentrations of total polycyclic aromatic hydrocarbons (PAHs) (r super(2)=0.5). Principal component analysis revealed that amphipod mortality was linked to a combination of several PAHs (phenanthrene, fluoranthene, pyrene, benzo(a)pyrene) and di-n-butylphthalate at southern San Francisco Bay sites. At northern San Francisco Bay sites, negative correlations were found between hsp64 levels and organotin compounds (MBT, DBT, TBT), and between hsp71 levels and the PAHs, benzo (b,k) fluoranthene and benzo (G,H,I) perylene, suggesting an inhibitory effect of these compounds on stress protein expression.

Weston, D. P., W. M. Jarman, et al. (2002). "An evaluation of the success of dredging as remediation at a DDT-contaminated site in San Francisco Bay, California, USA." Environmental Toxicology and Chemistry 21(10): 2216-2224.
Lauritzen Canal, a portion of San Francisco Bay near Richmond, California, USA, was heavily contaminated with dichlorodiphenyltrichloroethane (DDT) and dieldrin as a result of releases from a pesticide-formulating firm. In 1996 and 1997, 82,000 m(3) of contaminated sediment was removed from the canal by dredging. This study evaluated the success of the dredging based largely on body burdens of DDT and its metabolites (SigmaDDT) in resident biota, with some data on sediment- and water-contaminated levels and sediment toxicity testing. Sediment disturbance during dredging introduced a pulse oil : DDT Into the Lauritzen Canal ecosystem, and body burdens of fish and invertebrates increased 2- to 76-fold, depending on the species. Approximately 1 1/2 years after remediation, 11 of 14 indicators showed contamination comparable with or worse than the contamination that existed prior to dredging. Monitoring of mussels up to four years postdredging suggests some modest improvement, although the SigmaDDT body burden of canal mussels remained far above the norm for San Francisco Bay. The elevated SigmaDDT body burdens in biota that persisted for years after remediation reflect recent exposure and are not merely a result of slow metabolic elimination of the SigmaDDT pulse associated with dredging. Sediment SigmaDDT concentrations were low immediately after dredging, but within months, the canal bottom became covered with a veneer of fine sediment as contaminated as that that had been removed. The source of this material has not been conclusively established, but we suspect it came from slumping and erosion from the flanks of the canal beneath docks and around pilings where dredging was not done. In retrospect, either capping in place or more thorough dredging may have been more successful in reducing pesticide exposure of the biota, although there were difficulties associated with both alternatives.

Weston, D. P. and M. J. Lydy (2010). Anatomy of a rain event: urban runoff and toxicity in the American River throughout a winter storm. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Work during the winter of 2008/2009 using Hyalella azteca toxicity testing documented toxicity in the American River that had not previously been seen in past years of monitoring with Ceriodaphnia dubia and fathead minnow. The pyrethroid bifenthrin was linked to the toxicity through chemical analysis and Toxicity Identification Evaluation methods. River flow was particularly low that year, so further studies were conducted in the winter of 2009/2010 to determine if toxicity was again observed and to identify the major sources. This presentation will document the inputs of pyrethroids from a variety of sources during a single storm event in January 2010, and the resulting effect on water quality and toxicity in the main river. Discharge from 11 creeks, drains, and pump stations were sampled, with acutely toxic concentrations of pyrethroids found in 10 of them. The highest concentration was Carmichael Creek, with 32 times the bifenthrin EC50 (concentration that causes paralysis in half the H. azteca individuals in a test). On a loading basis, Chicken and Strong Ranch Sloughs were the largest contributors. The combined discharge of urban runoff from all sources during the rain event was approximately 1200 cfs, compared to the base flow in the river of 1460 cfs; in other words, the American River was about half urban runoff at the point it reached the Sacramento River. The portion of the river flowing through Sacramento attained bifenthrin concentrations approximately equal to the EC50 for H. azteca. The river remained toxic to H. azteca for at least the five-day monitoring period, affirming the ecological relevance of the standard four-day exposure period used in laboratory

toxicity tests.

Weston, D. P. and M. J. Lydy (2010). "Urban and Agricultural Sources of Pyrethroid Insecticides to the Sacramento-San Joaquin Delta of California." Environmental Science and Technology 44(5): 1833-1840.
While studies have documented the presence of pyrethroid insecticides at acutely toxic concentrations in sediments, little quantitative data on sources exist. Urban runoff, municipal wastewater treatment plants and agricultural drains in California’s Sacramento-San Joaquin River Delta were sampled to understand their importance as contributors of these pesticides to surface waters. Nearly all residential runoff samples were toxic to the amphipod, Hyalella azteca, and contained pyrethroids at concentrations exceeding acutely toxic thresholds, in many cases by 10-fold. Toxicity identification evaluation data were consistent with pyrethroids, particularly bifenthrin and cyfluthrin, as the cause of toxicity. Pyrethroids passed through secondary treatment systems at municipal wastewater treatment facilities and were commonly found in the final effluent, usually near H. azteca 96-h EC50 thresholds. Agricultural discharges in the study area only occasionally contained pyrethroids and were also occasional sources of toxicity related to the organophosphate insecticide chlorpyrifos. Discharge of the pyrethroid bifenthrin via urban stormwater runoff was sufficient to cause water column toxicity in two urban creeks, over at least a 30 km reach of the American River, and at one site in the San Joaquin River, though not in the Sacramento River.

Weston, D. P. and M. J. Lydy (2010). Urban runoff as a source of pyrethroid pesticides and resulting water column toxicity. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Whipple, A. (2010). Historical ecology of the Delta: Habitat characteristics of a fluvial-tidal landscape. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Whipple, A., R. Grossinger, D. Rankin, and J. Collins (2010). The historical Yolo Basin landscape. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Identifying target habitats for landscape-scale restoration of the highly modified Delta presents many challenges. One area of current focus is the Cache Slough/Yolo Basin landscape. Understanding the physical nature of this landscape and the ecological functions that existed prior to Euro-American modification offers a basis for designing sustainable habitat mosaics for the future. To reconstruct the historical landscape, our methods involve compilation and synthesis of 19th and 20th century cartographic, photographic, and textual data using GIS. We hypothesize that large-scale geomorphic, hydrologic, and climatic regimes of the Delta created unique ecological subsystems, within which habitat mosaics varied predictably along smaller scale physical gradients. The historical Yolo Basin is one example. From relatively dense dendritic Cache Slough tidal channel networks in the south to perennial marsh and lakes in the north, the Yolo Basin’s complex historical habitats reflect the subsystem’s physical gradients, such as hydroperiod. For example, our findings suggest that the historical lower Cache Slough contained channel densities similar to estimates elsewhere in the Estuary’s fresher marshes; densities which drop significantly across the transition from tidal to non-tidal floodplains. Large, shallow ponds occupied the transition from marsh margin to upland. Riparian vegetation varied in composition and structure in relation to such factors as the height of natural levees. The habitat mosaic was also strongly influenced by temporal environmental variability. The Yolo Basin received large volumes of freshwater from the Sacramento and its western tributaries in winter and spring, much less so in summer and fall. Many of the habitats were seasonally wet or ephemeral. Our research describes a level of historical habitat complexity and inter-connectivity that is unmatched in the contemporary Delta. Information compiled for this study will provide insight for restoration planning efforts in the Delta, including the Ecosystem Restoration Program and Bay-Delta Conservation Plan.

Whipple, J. A., M. B. Eldridge, et al. (1981). An ecological perspective of the effects of monocyclic aromatic hydrocarbons on fishes. Biological monitoring of

marine pollutants. S. J. Vernberg, A. Calabrese, F. P. Thurberg and W. B. Vernberg. New York, Academic Press: 483-551.
This paper briefly discusses the sources and fates of monocylic aromatic hydrocarbons (MAH) and summarizes their effects on fishes. Monocyclic aromatics discussed include: benzene, toluene, xylenes, ethylbenzene and substituted benzenes, in general. Examples of fish species are drawn from research in the San Francisco Bay-Delta area. Species discussed included: striped bass (Morone saxatilis), starry flounder (Platichthys stellatus), pacific herring (Clupea harengus pallasii), northern anchovy (Engraulis mordax) and Chinook salmon (Oncorhynchus tshawytscha). The possible relationship of selected genotypic differences to variability in uptake, bioaccumulation and effects is discussed for striped bass and starry flounder. Differences among the following life history stages also occur. Uptake, bioaccumulation, translocation and depuration of these components are discussed in relation to effects in terms of hypothesized modes of action and alterations of structure and function (morphology, physiology and behavior).

Whitcraft, C., B. Wallace, J. Olson, D. Talley, B. Grewell, and M. Psaros (2010). Control and management of perennial pepperweed invasion: An obtainable goal? 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Perennial pepperweed (Lepidium latifolium) is an aggressive, non-native weed that has invaded wetland and riparian areas throughout California. At Rush Ranch, a brackish marsh in San Francisco Bay NERR, we applied a three-pronged approach to understanding and managing pepperweed: (1) comparisons documenting impacts of perennial pepperweed on the sediment community and food web, (2) eradication experiments evaluating efficacy and non-target impacts of herbicide control in a tidal marsh and seasonal wetland context, and, (3) a symposium series bringing together researchers and managers to assess and share the current state of knowledge regarding ecological impacts, the invasion extent in the greater Bay Area, and best control practices. Within the high marsh, the presence of pepperweed significantly increased humidity and altered diversity and composition of surrounding plant, invertebrate and insect communities. We hypothesize that these changes will lead to cascading impacts throughout the food web. In mid and low elevations, the effects of perennial pepperweed are reduced due to constant inundation and soil saturation. In a seasonal wetland, two years of 2,4D were not effective in controlling pepperweed but had minimal non-target impacts on the native plant community. Imazypyr reduced pepperweed cover by more than 90% compared to untreated controls, but non-target impacts on the native plants were severe and persistent. We conducted similar herbicide treatments in a tidal marsh, comparing 2,4D, glyphosate and mowing combinations in the high and low elevations, and imazapyr and glyphosate combinations in low elevations over two years. Preliminary results indicate that imazapyr alone in the low marsh offers control with minimal non-target impacts. Herbicide data will indicate persistence and spread of this herbicide in the associated sediment. Our data provide important information about the consequences of perennial pepperweed invasion, about effective control techniques, and about development of integrated and informed decision processes for perennial pepperweed control.

White, J. R. (1986). "The striped bass sport fishery in the Sacramento-San Joaquin Estuary, 1969-1979." California Fish and Game 72: 17-37.
The fishery for striped bass Morone saxatilis in the Sacramento-San Joaquin Estuary is described from tag returns and a bay-area creel census. Annual harvest averaged 18% and was higher for bass greater than or equal to age 5. Annual catch ranged from about 100,000 to 400,000 fish and declined after 1976. Angler effort and success (catch/ang h) also declined in the late 1970's. The catch varied both seasonally and geographically; 80% of the catch occurred from May through November, mostly in San Francisco Bay. Fork length of bass in the catch averaged 65.1 cm, but exhibited a downward trend and varied among segments of the fishery. Age 3, 4, and 5 bass comprised two-thirds of the catch; age 4 typically was the most numerous group. Trends and anomalies in these data are discussed in relation to striped bass population characteristics, environmental factors and methodological bias.

Whitehead, A., K. M. Kuivila, et al. (2004). "Genotoxicity in native fish associated with agricultural runoff events." Environmental Toxicology and Chemistry 23(12): 2868-2877.
The primary objective of the present study was to test whether agricultural chemical runoff was associated with instream genotoxicity in native fish. Using Sacramento sucker (Catostomus occidentalis), we combined field-caging experiments in an agriculturally dominated watershed with controlled laboratory exposures to field-collected water samples, and we coupled genotoxicity biomarker measurements in fish with bacterial mutagenicity analysis of water samples. We selected DNA strand breakage as a genotoxicity biomarker and Ames Salmonella mutagenicity tests as a second, supporting indicator of genotoxicity. Data from experiments conducted during rainfall runoff events following winter application of pesticides in 2000 and 2001 indicated that DNA strand breaks were significantly elevated in fish exposed to San Joaquin River (CA, USA) water (38.8, 28.4, and 53.6% DNA strand breakage in year 2000 field, year 2000 lab, and year 2001 field exposures, respectively) compared with a nearby reference site (15.4, 8.7, and 12.6% DNA strand breakage in year 2000 field, year 2000 lab, and year 2001 field exposures, respectively). Time-course measurements in field experiments supported a linkage between induction of DNA strand breakage and the timing of agricultural runoff. San Joaquin River water also caused significant reversion mutation in two Ames Salmonella tester strains. Salmonella mutagenicity corroborated in-stream effects, further strengthening a causal relationship between runoff events and genotoxicity. Potentially responsible agents are discussed in the context of timing of runoff events in the field, concordance between laboratory and field exposures, pesticide application patterns in the drainage, and analytical chemistry data.

Wienke, S. M., and J.E. Cloern (1987). "The phytoplankton component of seston in San Francisco Bay." Netherlands Journal of Sea Research 21: 25-33.
Phytoplankton biomass (as carbon) was estimated from chlorophyll a concentrations (Chl a) and a mean value for the ratio of phytoplankton carbon to chlorophyll a in San Francisco Bay. The ratio was determined as the slope of a Model II regression of POC' against (Chl a), where POC' is total particulate organic carbon minus sediment-associated non-phytoplankton carbon. Samples from 30 fixed sites in the channel and lateral shoals of San Francisco Bay were collected once or twice a month from April to November 1980, and at irregular intervals in South Bay during 1984 and 1985. For all data the calculated mean value of phytoplankton C:Chl a was 51 (95% confidence interval = 47-54). No significant differences were found in the C:Chl a ratio between shallow and deep sites (where light availability differs) or between northern and southern San Francisco Bay (where phytoplankton community composition differs). Using the mean C:Chl a ratio of 51, we calculated that phytoplankton biomass constitutes about one third of seston carbon under most circumstances, but this fraction ranges from about 95% during phytoplankton blooms to less than 20% during spring periods of low phytoplankton biomass and high suspended sediment concentration.

Wikert, J. D., R. Barnett-Johnson, M. Workman, and P. Weber (2010). Hatchery or natural? A fourfold analysis of Mokelumne River chinook salmon. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.
Managing salmon populations in California’s Central Valley is currently a difficult task due to the challenge of identifying returning adults as hatchery or natural origin. Chinook salmon escapement or production estimates that don’t accurately account for the hatchery contribution may create the impression that natural populations are healthy, and that current management practices are successful at producing sustainable populations. The objective of this study was to quantify the relative contribution of natural versus hatchery origin fall-run Chinook salmon on the Mokelumne River. Four distinct methods were utilized to independently calculate the estimated ratio of hatchery vs. natural origin for the 2004 fall-run Chinook salmon adult escapement:1) Otolith Microchemistry, 2) Otolith Microstructure, 3) Coded-wire Tagging, and 4) Production (hatchery and in-river). Using the four methods we calculated that approximately 3% of the adult fall-run Chinook salmon returning to the Mokelumne River began life in a river environment. Given recent publications citing negative impacts to natural populations of

salmonids from hatchery practices, fall-run Chinook populations should be further assessed in efforts to determine accurate population numbers for naturally produced fish.

Wikert, J. D., and C. Mesick (2010). Size does matter: Gravel size and chinook salmon egg survival. 6th Biennial Bay-Delta Science Conference. Poster paper presented at the Sacramento Convention Center, Sacramento, California.

Numerous spawning gravel augmentation projects for Chinook salmon and steelhead have been undertaken in the last decade in California's Central Valley. Little evaluation of the appropriate size composition of the added gravel to ensure survival of eggs to hatching has been undertaken. We conducted this study to determine if the presence of smaller size coarse sediments were necessary for successful egg incubation. We reared fresh spawned eggs in five egg chambers buried in artificial redds in each of four different gravel mixtures in the Stanislaus River. Comparisons in egg survival rates and inter-gravel flows were made between gravel mixtures cleaned with 6.35mm, 9.52mm and 25.4mm screens, as well as natural gravels. Survival exceeded 70% for natural gravels and gravels with a minimum size less than or equal to 9.5 mm. Gravels with a minimum size of 25.4 mm had an average survival of less than 1 percent. Gravel mixtures used to restore spawning habitat should contain particles smaller than 15mm to increase the survival of Chinook salmon eggs.

Wilkerson, F., A. Parker, R. Dugdale, and A. Marchi (2010). Different response types of phytoplankton to changing nutrient regimes in Suisun Bay: bottom-up effects of ammonium and nitrate. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Worldwide, estuaries receive large fluxes of nutrients including reduced forms of nitrogen (e.g. ammonium) as the result of human activities. One major source is effluent from municipal waste water treatment plants. A high relative contribution of ammonium versus nitrate to the dissolved inorganic nitrogen (DIN) pool may have detrimental consequences on primary production and phytoplankton accumulation. Elevated ammonium precludes phytoplankton use of nitrate (the largest pool of DIN in the SFE) limiting the magnitude of phytoplankton biomass accumulation. In the northern San Francisco Estuary/Delta these bottom-up effects impact the food web and may contribute to the Pelagic Organism Decline. To assess how SFE phytoplankton in the northern estuary and Delta respond to elevated ammonium concentrations supplied by the Sacramento River, enclosure experiments were conducted with water from Suisun Bay and Rio Vista. Nutrient drawdown and uptake, primary production, and chlorophyll accumulation were tracked and compared to measurements made in enclosures with Central Bay water. Three types of response were identified; Type I in Central Bay was characteristic of healthy phytoplankton in low ammonium, that were able to drawdown all available DIN (all ammonium and nitrate) and accumulate chlorophyll within 72 hours. Type II response in Suisun Bay was delayed in time, usually with ammonium drawdown by 96 hours, little nitrate uptake and chlorophyll accumulation peak by 144 hours. Type III in Rio Vista, where ammonium was the highest concentration, there was a very poor response by the phytoplankton with little DIN drawdown or chlorophyll accumulation, even after 144 hours. This approach allows a way to classify the productivity potential or quality of the water and may suggest a management tool for increasing production. Evaluating the role of ammonium, that is likely a WWTP product, on the SFE food web is essential for long term ecosystem sustainability.

Wilkerson, F. P., R. C. Dugdale, et al. (2006). "Phytoplankton blooms and nitrogen productivity in San Francisco Bay." Estuaries and Coasts 29(3): 401-416.

San Francisco Bay has been considered an HNLC or HNLCr (high nutrient low chlorophyll or low growth) region with nonlimiting concentrations of inorganic nutrients yet low standing stocks of phytoplankton. Most of the studies leading to this conclusion come from the South Bay and little is known about nutrient processes and phytoplankton productivity in the northern and central parts of the estuary. Data collected over 3 yr (1999-2003) in Suisun, San Pablo, and Central Bays describe the availability of dissolved inorganic nitrogen (DIN), silicate, and phosphate and the seasonal variability in phytoplankton abundance. Rate measurements of fractionated nitrogen productivity provide the relative contributions of different forms of DIN (ammonium and nitrate) and different sized phytoplankton to the development of seasonal phytoplankton blooms. Regional differences in bloom dynamics are observed with Suisun Bay, the least saline, highest nutrient, most turbid region having less phytoplankton biomass and productivity than San Pablo and Central Bays, except in the abnormally wet spring of 2000. Spring blooms in San Francisco Bay are driven primarily by high rates of nitrate uptake by larger phytoplankton cells following a period of increased ammonium uptake that depletes the ambient arnmonium. The smaller occasional fall blooms are apparently fueled mostly by ammonium uptake by small sized phytoplankton. The data suggest that the HNLC condition in the northern and central parts of San Francisco Bay is due primarily to light availabitity modulated by the interaction between ammonium and nitrate, and the relative amounts of the two forms of the DIN pool available to the phytoplankton.

Williams, J. E., and C.D. Williams (1991). The Sacramento River winter chinook salmon: Threatened with extinction. California's Salmon and Steelhead: The Struggle to Restore an Imperiled Resource. A. Lufkin. Berkeley, CA, University of California Press: 105-115.
        The Sacramento River winter chinook salmon are nearing extinction. The unacceptable loss of this distinct and valuable race of salmon would be the result of conscious management decisions that demonstrated a lack of concern for the needs of the species. The winter chinook salmon are adapted to entering the main Sacramento River in late winter and spawning far upstream during the early months of the Central Valley's long, hot summer. Their ancestral spawning grounds were in the McCloud River, a tumbling, spring-fed tributary of the upper Sacramento. Eggs hatched and fry matured in the cold, consistent flows of the McCloud, seemingly oblivious to the hot summer weather.

All this changed when Shasta and Keswick dams were built on the Sacramento. Migrating adults, blocked by the dams, no longer could reach historic spawning areas. Pollution, water diversions, and stream channelization also exacted their toll. As recently as 1969, more than 100,000 spawners were tallied. Annual counts from 1982 to 1988 average only 2,334 adult fish—more than a 97 percent decline. At the reduced population levels of recent years, extinction is likely from continued habitat losses or a chance event such as drought or flood.

This disastrous decline has called fishery biologists, anglers, and environmentalists to action. They began efforts in 1985 to protect the winter chinook salmon pursuant to federal and state endangered species acts. Faced with the precedent of possibly listing a salmon as endangered or threatened and having to restrict water development in the Sacramento Valley, the National Marine Fisheries Service and the California Fish and Game Commission hesitated to apply the protections afforded by strong endangered species laws and ultimately did so only after extensive legal wrangling and a further precipitous decline to only five hundred and seven spawners in 1989. This chapter traces the unique life history of the Sacramento River winter chinook, efforts to save them from extinction, and the anticipated impact of endangered species protection on sport and commercial anglers, water users, and the fish.

Williams, J. G. (1999). "Stock dynamics and adaptive management of habitat: An evaluation based on simulations." North American Journal of Fisheries Management 19(2): 329-341.
        Simulations based on the Ricker and Beverton–Holt stock–recruitment models illustrate the difficulties with developing information about the effectiveness of habitat restoration efforts from the relation between measurements of habitat and populations of anadromous fishes. The relation between the two is confounded by density-dependent mortality and variable density-independent mortality and is masked by measurement errors. The simulations are considered in terms of populations of fall-run (ocean-type) chinook salmon Oncorhynchus tshawytscha from the Sacramento–San Joaquin river system of central California, where major federal and state efforts are underway to restore anadromous fish populations, as well as brackish and freshwater ecosystems. The simulations show that to implement effective adaptive management of salmon habitat, these efforts must move beyond a trial and error approach in which efforts to restore salmon habitat will be evaluated by

population responses. A more promising alternative is evaluating restoration efforts by identifying and testing hypotheses about the mechanisms or processes that relate the restoration actions to populations.

Williams, J. G. (2001). Chinook salmon in the lower American River, California's largest urban stream. Contributions to the Biology of Central Valley Salmonids. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 2: 1-38.
The American River now supports a mixed run of hatchery and naturally-produced fall-run chinook averaging about 30,000 spawners;the spring-run was lost to dams. Salmon in the river have been much studied over the last 20 years, largely because of litigation over proposed diversions, but much uncertainty remains about various aspects of their biology and about the environmental conditions needed to support them. This paper briefly reviews what is known and not known about salmon in the American River and makes recommendations for future work.

Williams, J. G. (2006). "Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California." San Francisco Estuary and Watershed Science 4(3): Article 2.

Williams, J. G., J. J. Anderson, et al. (2007). "Monitoring and Research is Needed to Manage the Recovery of Threatened and Endangered Chinook and Steelhead in the Sacramento-San Joaquin Basin." NOAA Technical Memorandum NMFS SWFSC(399): 15 pp.
In this report, we assess whether existing monitoring activities in the Central Valley are sufficient to determine if biological recovery goals are being met, and make recommendations for monitoring and research that could provide critically-needed information for effective management of Chinook salmon and steelhead beyond simple viability assessments. Assessing population status requires, at a minimum, estimates of abundance on the spawning grounds and the fraction of naturally-spawning fish that are of hatchery origin. We find that such data are generally available for independent populations of Chinook salmon, but are almost entirely unavailable for steelhead populations. Effective monitoring of steelhead run sizes at the population scale is needed urgently. Effective management of listed salmonids requires more information than simply whether populations and ESUs are achieving viability targets. We anticipate that managers will need information on the response of salmonid populations to regional climate change, the use of freshwater habitat, mechanisms and magnitude of mortality in freshwater and the ocean, age- and stock-specific harvest rates, trends in effective population size and genetic diversity within and among populations, the effects of hatchery operations on naturally spawning populations, how to go about reintroducing fish to reconnected or restored habitats, and the factors controlling and the implications of variable life history tactics of steelhead. We discuss why these information gaps need to be filled, and offer some suggestions on promising approaches to filling them. Finally, we recommend that new and existing data should be made accessible to researchers and managers through a central data portal that can aggregate information from the many existing databases.

Williams, M., K. Cayce, M. May, J. Oram, C. Grosso, and J.N. Collins (2010). Bay area base map of aquatic resources. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The single-most important technical tool for coordination of environmental regulation, management, science, and education is a common base map. A common map helps define and visualize environmental problems and alternative solutions; organize multiple projects for mutual benefit and overall effectiveness; track projects and associated data; and understand a given project in the context of other aquatic resources and projects. This is especially important for land use and watershed planning and management. Water quality and flood control, water supply planning, sediment and stormwater management, species recovery and habitat conservation are difficult to coordinate unless represented spatially on a common base map. Few comprehensive, regional maps created with standardized methods are available to assist planning efforts. When maps exist, they frequently lack consistent mapping standards for habitat and feature classification, minimum mapping units, source data, and even scale. Both the California Wetland Monitoring Workgroup

and the State Water Board's proposed Wetland and Riparian Area Protection Policy call for a standardized Base Map. SFEI and SCCWRP are piloting regional base map standards for the Bay Area and Southern California coast. The pilot maps include extensive classification of all mapped features needed to accurately represent all surface waters and their riparian areas. The Base Map's level of detail and accuracy were specified to ensure resolution and quality to meet the needs of the region's agencies and scientists. The Bay Area Base Map will be integrated into the State's Wetlands Portal, a publicly available repository for tracking changes in the extent and condition of aquatic habitat as affected by environmental projects, land use, and climate change. This will improve site-specific and watershed-specific data and information sharing. We will discuss mapping standards and the modeling methodology used to estimate riparian extent based on vegetation and hillslope processes. The Wetlands Portal will be demonstrated.

Williams, P. B. (1989). "Managing freshwater inflow to the San Francisco Bay Estuary." Regulated Rivers - Research and Management 4(3): 285-298.
The watershed of California's Central Valley drains into San Francisco Bay, the largest estuary on the Pacific Coast. The water resources of the Valley have been intensively exploited, particularly in the last 50 years, with the construction of large-scale irrigation systems. About half the 35 km super(3) average annual freshwater inflow to the estuary is now diverted, with up to 85 per cent in dry years. These diversions are now having significant adverse effects on the estuarine ecosystem including substantial declines in the economically significant anadromous fishery. A set of freshwater flow and salinity standards has been proposed and is described in this paper.

Williams, P. B. and J. T. Hollibaugh (1987). A salinity standard to maximize phytoplankton abundance by positioning the entrapment zone in Suisun Bay, Phillip Williams & Associates; Report N. 412-4.

Williams, P. B. and M. K. Orr (2002). "Physical Evolution of Restored Breached Levee Salt Marshes in the San Francisco Bay Estuary." Restoration Ecology 10(3): 527-542.
Since 1972 over 940 ha (2,300 ac) of leveed former salt marsh sites around San Francisco Bay have been restored to tidal action, purposely or through natural processes. The evolution of these sites can inform predictions of rates of marshplain evolution and establishment of tidal channel systems. A review of the history of 15 re-flooded sites ranging in size from 18 to 220 ha (45 to 550 ac) and in age from 2 to 29 years indicates that marshplain vegetation with more than 50% cover was established at nine of the sites within 4 to 20 years. The remaining six sites aged 2 to approximately 20 years continue to be less than 50% vegetated. The evolution of these sites is consistent with the following simple conceptual model of the physical evolution of restored tidal marshes in subsided breached sites. Initially, deposition of estuarine sediment builds up mudflats that allow vegetation establishment once elevations are high enough for vegetation to survive. Sites that are initially lower in the tidal frame take longer to vegetate than those that are initially higher. Three factors appear to retard the time frame for vegetation establishment: limited estuarine suspended sediment supply, erosion of deposited estuarine muds by internally generated wind waves, and restricted tidal exchange. These factors affect evolution more significantly in larger sites. The comparatively short time frame for vegetation colonization and marshplain evolution experienced in earlier, smaller, and/or less subsided breached levee restorations may not necessarily be replicable by simple levee breaching on larger subsided restoration sites now being planned. Our review of the 15 sites also indicates that the formation of tidal channels within the marshes is greatly dependent on whether and how high the site was filled before breaching. Filled sites at high intertidal elevations (above approximately 0.3 m below mean higher high water) can vegetate quickly but after several decades may show little development of tidal channels.

Williams, P. B., M. K. Orr, et al. (2002). "Hydraulic Geometry: A Geomorphic Design Tool for Tidal Marsh Channel Evolution in Wetland Restoration Projects." Restoration Ecology 10(3): 577-590.
Empirical hydraulic geometry relationships for tidal marsh channels are a practical geomorphically based design tool that can assist in the planning of tidal

wetland restoration projects. This study provides hydraulic geometry relationships for predicting the depth, width, and cross-sectional area of mature tidal channels as functions of contributing marsh area or tidal prism. The relationships are based on data from San Francisco Bay coastal salt marshes ranging in size from 2 to 5,700 ha. These hydraulic geometry relationships refine and expand on earlier relationships. Relationships for mature marshes can be used to predict the direction and rate of evolution of a channel in an immature or perturbed marsh system. Channel evolution data for three youthful tidal channels, ages 4 to 13 years, suggest that the channels are converging on their predicted equilibrium morphology. Two channels are eroding in response to significant increases in upstream tidal prism. They have enlarged first by deepening, in one case after 13 years to beyond the predicted equilibrium depth, and then widening through slumping of the channel banks. The third channel, a new one forming in a depositional mudflat, is converging on its equilibrium morphology after 13 years but will likely take several decades to equilibrate.

Wilson, A. M., G. Garven, et al. (1999). "Paleohydrogeology of the San Joaquin Basin, California." Bulletin of the Geological Society of America 111(3): 432-449.
Mass transport can have a significant effect on chemical diagenetic processes in sedimentary basins. This paper presents results from the first part of a study that was designed to explore the role of an evolving hydrodynamic system in driving mass transport and chemical diagenesis, using the San Joaquin Basin of California as a field area. We use coupled hydrogeologic models to establish the paleohydrogeology, thermal history, and behavior of nonreactive solutes in the basin. These models rely on extensive geological information and account for variable-density fluid flow, heat transport, solute transport, tectonic uplift, sediment compaction, and clay dehydration. In our numerical simulations, tectonic uplift and ocean regression led to large-scale changes in fluid flow and composition by strengthening topography-driven fluid flow and allowing deep influx of fresh ground water in the San Joaquin Basin. Sediment compaction due to rapid deposition created moderate overpressures, leading to upward flow from depth. The unusual distribution of salinity in the basin reflects influx of fresh ground water to depths of as much as 2 km and dilution of saline fluids by dehydration reactions at depths greater than similar to 2.5 km. Simulations projecting the future salinity of the basin show marine salinities persisting for more than 10 m.y. after ocean regression. Results also show a change from topography- to compaction-driven flow in the Stevens Sandstone at ca. 5 Ma that coincides with an observed change in the diagenetic sequence. Results of this investigation provide a framework for future hydrologic research exploring the link between fluid flow and diagenesis.

Wilson, C. M. (2011). THE REASONABLE USE DOCTRINE
&
AGRICULTURAL WATER USE EFFICIENCY. A Report to the State Water Resources Control Board
and
the Delta Stewardship Council: 17.
The Reasonable and Beneficial Use Doctrine (Reasonable Use Doctrine) is the cornerstone of California’s complex water rights laws. All water use must be reasonable and beneficial regardless of the type of underlying water right. No one has an enforceable property interest in the unreasonable use of water.

Water use has been found to be unreasonable in a variety of circumstances. However, the application of the Reasonable Use Doctrine tends to be a cumbersome, multistep process and has largely been reactive, where someone claims another person’s use of water is unreasonable and uses a judicial or administrative forum to resolve the complaint.

The purpose of the report is to review the breadth of the Reasonable Use Doctrine, which can affect all water uses, including urban, hydropower, recreation, environment, and agriculture, and then to focus on how the Reasonable Use Doctrine can be used promote efficient use of water in the agricultural sector.

The underlying premise of this report is that the inefficient use of water is an

unreasonable use of water. Accordingly, the Reasonable Use Doctrine is available prospectively to prevent general practices of inefficient water use. Indeed, the Reasonable Use Doctrine, as set forth in the State Constitution and California Statutes is broad and inviolate in scope. As interpreted by case law and administrative decisions and used to its full potential, it can comprehensively address the inefficient use of water in California.

The focus on agriculture in this paper is grounded in two principles: small changes in agricultural water use efficiency can produce significant amounts of "wet" water and California's agricultural sector, which has tested and proven many conservation practices, is in a position to identify economically justified and locally cost effective water management techniques that retain the value of return flows to both downstream users and other environmental beneficiaries.

Maximizing the efficient use of water by projects that reduce consumptive water use is particularly important for the Sacramento/San Joaquin Delta. More efficient use of water upstream of the Delta can increase water flows into the Delta. More efficient water use within the Delta can increase Delta outflows. Reducing the amount of agricultural return Delta flow, both upstream of and in the Delta, has important water quality benefits.

Wilson, C. M. (2011). THE STATE WATER RESOURCES CONTROL BOARD'S
ROLE IN IMPLEMENTING THE DELTA PLAN. A Report to the State Water Resources Control Board
and
the Delta Stewardship Council: 8.
The Sacramento-San Joaquin Delta Reform Act of 2009 established a governance structure that directs efforts across state agencies to develop a legally enforceable Delta Plan. Water Code § 85001(c). The Delta Plan creates a comprehensive, long-term management plan for the Delta. Water Code § 85059.

The Delta Stewardship Council must develop, adopt, and commence implementation of the Delta Plan on or before January 1, 2012 to further the co-equal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. Water Code § 85300. The Delta Plan may also identify specific actions that state or local agencies may take to implement specified subgoals and strategies.

The State Water Resources Control Board (State Water Board), as the state's principal water resources regulatory agency, has the authority to help implement many of these goals, subgoals, and strategies. It is the purpose of this report to list these authorities and describe how they may be used to help implement the Delta Plan.

Wilson, C. M. (2011). STATEMENTS OF WATER DIVERSIONS AND USE:
PROVIDING A BETTER PICTURE OF WATER USE IN THE DELTA. A Report to the State Water Resources Control Board
and
the Delta Stewardship Council: 18.
Since 1966, California has had a statutory program entitled "Statements of Water
Diversions & Use." While the program's intent was to broadly gather information regarding diversion of water from streams, limitations in the law made the program less
than comprehensive. For example, until recently most Delta diverters were exempted from coverage. However, recent legislation has breathed new life into the Statements of Water Diversions and Use Program (Statements Program).

The purpose of this report is to outline the history of the Statements Program and explain recent statutory changes that will enable the program to more comprehensively
fulfill its original intent of providing meaningful information regarding water diversion and

use, particularly in the Delta. The report also underscores a serious funding problem
that threatens the integrity of the Statements Program and explores issues related to
the new requirement for diverters to provide monthly records of water diversion based
on the use of best available technologies.

Wilson, C. M. (2012). IMPROVING WATER RIGHT ENFORCEMENT AUTHORITY. A Report to the State Water Resources Control Board and the Delta Stewardship Council: 10.
Compared to its water quality authority, the State Water Resources Control Board’s (State Water Board) water right monitoring and enforcement authority is weak. Deficiencies include:
1) There are no direct penalties for violation of the terms and conditions of a water right permit or license. The State Water Board may only impose penalties where the violation amounts to an unauthorized diversion or use of water, or where the State Water Board has already issued a Cease and Desist Order for the violation and that violation continues.
2) While the State Water Board has general authority to conduct investigations, its authority to require water right monitoring and reporting, and to allow access for investigations should be more specific. There are no Administrative Civil Liabilities (ACLs) for failure by licensees to provide required reports.
3) For violation of the State Constitutional Prohibition against the waste or unreasonable use of water, a convoluted process of issuing an order finding a violation, issuing a Cease and Desist Order of continuing violation, and then conducting a third proceeding to impose ACL must currently be followed.

Enhancing the State Water Board’s water rights authority will benefit the state’s ability to improve water supply planning and make sound water use decisions. Delayed or postponed compliance can foster situations where individuals make decisions, take action, or fail to take action that are adverse to the public interest in maximizing the reasonable and beneficial use of water and in protecting the environment. Efficient and timely water rights enforcement promotes a level playing field where all persons must play by the same rules and not conduct unfair business practices.

Weak enforcement authority and an unnecessary abundance of process are apparent when comparing existing water right enforcement authorities with water quality enforcement laws. While the discharge of waste to water is a privilege, not a right, water is owned by the people of the state and the property right extends to the use of this shared resource. Accordingly, the enforcement program in the water right arena should be enhanced to approach that of water quality enforcement authorities.

A look at Water Code section 1052 exemplifies weaknesses in water right enforcement authority. This section presently authorizes the State Water Board to impose ACLs, which are monetary penalties, for trespass which has been interpreted to include an unauthorized diversion of or use of water. The State Water Board also has limited authority to impose ACLs for violations of Cease and Desist Orders (Water Code section 1845). However, ACLs cannot be directly imposed for other water right violations such as permit terms violations and failures to perform monitoring and reporting. In analogous water quality enforcement situations, the State and Regional Water Boards have broad authority to require reports and impose ACLs (See generally Water code sections 13201, 13265, 13267, 13268, 13323, and 13350).

In 2009, the State Water Board was granted authority to impose ACLs for persons who violate the requirement for filing Statements of Water Diversions and Use (Water code section 5107). Similar authority to impose ACLs for violations by water right permittees and licensees is lacking.

Finally, the current process for enforcing the constitutional prohibition against the waste or unreasonable use of water is unnecessarily convoluted. First an Order finding a violation must be adopted. Second, a Cease and Desist Order must be issued for a continuing violation. Lastly, a third proceeding must be conducted to assess ACLs. Notice by personal service or certified mail is required at each step. If service is not completed, the process cannot continue. Service options similar to the ones contained in the water quality enforcement program (see Water Code 13323) should be made available.

Wilson, C. M. (2012). TERM 91: STORED WATER BYPASS REQUIREMENTS. A Report to the State Water Resources Control Board and the Delta Stewardship Council, By Craig M. Wilson, Delta Watermaster: 11.
The purpose of this report is to explore the enhanced use and more vigorous enforcement of diversion curtailments as a means to achieve flow standards. This subject matter is relevant to the Delta even through the Projects are under a present and legal obligation to meet existing flows standards. Why? First, the flow standards are likely to be revised in a way that will modify the amount of stored water that must be released. It will become harder for the projects to meet both the revised flow standards and delivery obligations. Violations of the flow standards are more likely to occur in the absence of robust stored water curtailment efforts. When stored water releases are being made to achieve flow standards, persons should not be able to take such water before it reaches the Delta. Requiring other diverters to help achieve the standards increases the likelihood they will be met. Diversion curtailments are a logical way to help ensure compliance with the standards. The State Water Board has imposed diversion curtailments on certain junior water holders through its Term 91 process. Expansion of such efforts would be one way to address the question of where the water will come from to meet revised flow requirements. Greater compliance with curtailment requirements should also be implemented.1

The rest of this report will focus on 1) better enforcement of existing curtailment requirements and 2) the types of proceedings and other measures that can be taken to ensure that stored flows are not diverted, but rather are bypassed when they are needed to meet Delta flow standards.

Wilson, C. M. (2012). Water Right Compliance and Enforcement in the Delta. A Report to the State Water Resources Control Board and the Delta Stewardship Council: 9.
On July 10, 2008 the State Water Resources Control Board (State Water Board) adopted a Strategic Workplan for Activities in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Strategic Workplan or Workplan). Resolution No. 2008-0056. The purpose of the Strategic Workplan was to prioritize and describe the scope of individual activities that will be completed to protect beneficial uses of water in the Bay-Delta.

One of the nine workplan activities set forth in the Strategic Workplan addresses the following subject: Water Right Compliance, Enforcement, & Other Activities to Ensure Adequate Flows to Meet Water Quality Objectives. (Workplan, pages 6, 14). Included in the activities is the investigation of whether illegal diversions and violations of water right permit and license conditions are occurring in the Bay-Delta watershed and taking action to address those violations. The objective is to fulfill the State Water Board’s statutory responsibility (see Water Code sec. 1825) to vigorously enforce water rights by preventing unauthorized diversions of water, violations of terms of water rights permits or licenses, and violations of the prohibition against the waste or unreasonable use of water. Concurrently, compliance inspections will be performed to assess overall existing water rights and compliance with terms and conditions. (Workplan, page 1).

There are approximately 3000 diversions of water in the Delta. About 2700 diversions are made under riparian or pre-1914 claims of water rights. Many of the claims have not been verified and there may be additional diversions taking place where no claim of water right has been identified. Accordingly, the number and magnitude of illegal diversions in the Bay-Delta watershed is unknown. However, the Workplan indicated that it could be quite significant (Workplan, page 83). For example, records revealed that many parcels within the Delta islands are not contiguous to Delta waterways. Yet aerial photographs and other evidence indicate that such parcels have been irrigated and are likely supplied with water diverted from Delta channels. While many of these diversions have retained riparian water rights and/or possess valid pre-1914 appropriative water rights, the basis of right must be investigated

to make that determination (Workplan, page 83). Accordingly, the Strategic Workplan indicates that the State Water Board will employ its statutory responsibilities to investigate whether illegal diversions are occurring and take action to address those illegal diversions (Workplan, page 83). While this project will initially focus in the Delta, other areas of the Bay-Delta watershed are also subject to investigations and potential enforcement action.

Winans, G. A., D. Viele, et al. (2001). "An Update of Genetic Stock Identification of Chinook Salmon in the Pacific Northwest: Test Fisheries in California." Reviews in Fisheries Science 9(4): 213-237.
Analyzing the stock composition of mixed-stock fisheries using genetic stock identification (GSI) procedures was developed for chinook salmon in the early 1980s when an incipient baseline was focused in the Columbia River basin. The current coastwide baseline of allozyme (protein) genetic loci includes approximately 75% of the major contributing populations from California to western Alaska for over 30 polymorphic loci. We review the 2-decade history of GSI studies of chinook salmon in fishery applications in the Pacific Northwest. By summarizing GSI results for four test fisheries in California, we demonstrate the use of a regional segment of the current baseline to monitor critically depleted stocks. Average F sub(ST) is 0.099, with 12 loci F sub(ST) > 0.05, in a 28 locus/53 population dataset from southern Oregon to southern California. Seven stock groups are recognized based on a multilocus pattern of differentiation that coincides with watersheds and coastal affiliations. Simulated mixture analyses indicate that stock groups are well resolved: percent correct assignment is 83% for Central Valley spring-run, but >92% for all other groups. Simulated mixture analyses also indicated that it is difficult to distinguish between mixtures with low levels (less than or equal to 1%) of Central Valley winter- or spring-run stocks given the present dataset. GSI estimates for four test fisheries indicate that Central Valley fall- and late fall-run chinook salmon comprised the majority of each mixture (89 to 95%). Critical or endangered stock groups were detected in test fisheries in the 1997 Point Conception fishery (3% Sacramento River winter-run) and in the 1999 Bodega Bay fishery (2.8% Upper Klamath-Trinity rivers). Preliminary regional baselines for intron and microsatellite loci show promise for added stock discrimination among chinook salmon populations. GSI projects are increasingly involving multiple agencies and using multicharacter procedures. Continued GSI monitoring of chinook salmon stocks with nonlethal sampling for protein and DNA-based characters will play a prominent role in conservation and fisheries management in the 21st century.

Winder, M., and J.E. Cloern (2010). "The annual cycles of phytoplankton biomass." Philosophical Transactions of the Royal Society B Biological Sciences: 12.
Terrestrial plants are powerful climate sentinels because their annual cycles of growth, reproduction and senescence are finely tuned to the annual climate cycle having a period of one year. Consistency in the seasonal phasing of terrestrial plant activity provides a relatively low-noise background from which phenological shifts can be detected and attributed to climate change. Here, we ask whether phytoplankton biomass also fluctuates over a consistent annual cycle in lake, estuarine-coastal and ocean ecosystems and whether there is a characteristic phenology of phytoplankton as a consistent phase and amplitude of variability. We compiled 125 time series of phytoplankton biomass (chlorophyll a concentration) from temperate and subtropical zones and used wavelet analysis to extract their dominant periods of variability and the recurrence strength at those periods. Fewer than half (48%) of the series had a dominant 12-month period of variability, commonly expressed as the canonical spring-bloom pattern. About 20 per cent had a dominant six-month period of variability, commonly expressed as the spring and autumn or winter and summer blooms of temperate

lakes and oceans. These annual patterns varied in recurrence strength across sites, and did not persist
over the full series duration at some sites. About a third of the series had no component of
variability at either the six- or 12-month period, reflecting a series of irregular pulses of biomass.
These findings show that there is high variability of annual phytoplankton cycles across ecosystems,
and that climate-driven annual cycles can be obscured by other drivers of population variability,
including human disturbance, aperiodic weather events and strong trophic coupling between
phytoplankton and their consumers. Regulation of phytoplankton biomass by multiple processes
operating at multiple time scales adds complexity to the challenge of detecting climate-driven
trends in aquatic ecosystems where the noise to signal ratio is high.

Winder, M. and A. Jassby (2011). "Shifts in Zooplankton Community Structure: Implications for Food Web Processes in the Upper San Francisco Estuary." Estuaries and Coasts 34(4): 675-690.
Zooplankton are an important trophic link and a key food source for many larval fish species in estuarine ecosystems. The present study documents temporal and spatial zooplankton dynamics in Suisun Bay and the Sacramento–San Joaquin Delta—the landward portion of the San Francisco Estuary (California, USA)—over a 37-year period (1972–2008). The zooplankton community experienced major changes in species composition, largely associated with direct and indirect effects of introductions of non-native bivalve and zooplankton species. A major clam invasion and many subsequent changes in zooplankton abundance and composition coincided with an extended drought and accompanying low-flow/high-salinity conditions during 1987–1994. In the downstream mesohaline region, the historically abundant calanoid copepods and rotifers have declined significantly, but their biomass has been compensated to some extent by the introduced cyclopoid Limnothoina tetraspina. The more upstream estuary has also experienced long-term declining biomass trends, particularly of cladocerans and rotifers, although calanoid copepods have increased since the early 1990s due to the introduced Pseudodiaptomus spp. In addition, mysid biomass has dropped significantly throughout the estuary. Shifts in zooplankton species composition have also been accompanied by an observed decrease in mean zooplankton size and an inferred decrease in zooplankton food quality. These changes in the biomass, size, and possibly chemical composition of the zooplankton community imply major alterations in pelagic food web processes, including a drop in prey quantity and quality for foraging fish and an increase in the importance of the microbial food web for higher trophic levels.

Winder, M., A. D. Jassby, et al. (2011). "Synergies between climate anomalies and hydrological modifications facilitate estuarine biotic invasions." Ecology Letters 14(8): 749-757.

Wing, S. R., L. W. Botsford, et al. (1998). "Meroplanktonic distribution and circulation in a coastal retention zone of the northern California upwelling system." Limnology and Oceanography 43(7): 1710-1721.
Previous studies have shown that settlement of several crab species along

the coast north of Point Reyes (38 degree 00'N, 123 degree 00'W) occurs primarily during relaxation from upwelling, when warm water flows poleward from the Gulf of the Farallones. During 1994 and 1995 we sampled planktonic larval distributions and hydrography both south and north of Point Reyes during upwelling to test whether high concentrations of crab and rockfish larvae were concentrated in the source of the relaxation flow to the south of Point Reyes. An upwelling plume off Point Reyes and an "upwelling shadow," indicated by warmer, less saline water in the northern Gulf, were evident in both years, as were frontal regions that marked the boundaries between water types of three different types: (1) newly upwelled, (2) oceanic, and (3) San Francisco Bay outflow. In addition, there was a fourth type, termed Gulf water, that was a mixture of these three types. Concentrations of larvae of cancrid, pinnotherid, and "coastal" crabs and rockfishes were high south of Point Reyes but were low or absent in the newly upwelled water north of the point. Within the upwelling shadow, these meroplankton taxa were associated with different water masses. Several intertidal crab species and early-stage cancrid crabs were concentrated in San Francisco Bay outflow water, and coastal Gulf water late-stage cancrid crabs, early- and late-stage pinnotherid crabs, and rockfishes were concentrated at the frontal region between newly upwelled and Gulf water. Of the taxa examined, only rockfishes were found offshore in oceanic water. The high concentrations of meroplankton observed suggest that the Gulf of the Farallones is an important retention area for larvae that settle into coastal populations in the Gulf and to the north via poleward transport during upwelling relaxation.

Winham-Myers, L., M. Marvin-DiPasquale, K. Ward, J. Agee, L. Kieu, and E. Kakouros (2010). Methylmercury export from a restored tidal marsh: Crissy Field, Golden Gate National Recreation Area, San Francisco, CA. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Due to its small size, a single inlet and outlet, and a tidally-dominated water budget , the restored salt marsh at Crissy Field, Golden Gate National Recreation Area provides a good opportunity to construct a total mercury (THg) and methylmercury (MeHg) mass balance for a tidal wetland. We sought to determine a) the extent to which Crissy Marsh was a source or a sink of MeHg to San Francisco Bay, b) where and when MeHg is produced within the marsh, and c) the MeHg concentrations in sediment and water during and outside of periodic extended flooding brought on by inlet closure events. Surface water at a well-mixed station within Crissy Marsh showed surprisingly high aqueous MeHg concentrations (>1 ng L-1) given its low sediment THg concentrations. A 24-hour sampling event over a full asymmetrical tidal cycle was conducted during August 2008. Particulate and filter-passing (0.45m) THg and MeHg concentrations were assessed, along with key water quality parameters including concentrations of chlorophyll a and total suspended solids. Concentrations of THg and MeHg were coupled to flow calculations from a USGS-tailored hydrodynamic model developed for tidal prism relationships at this site. The resulting load calculations demonstrated that for this 24-hour period, the marsh was a net source of dissolved MeHg to the bay and a net sink of particulate THg from the bay. Overall total Hg flux was not significant with compounded errors. Spatial and temporal patterns of sediment %MeHg suggest that microbial production of MeHg was most active in the low intertidal (cordgrass-dominated) zone. We conclude that mercury present in Crissy Marsh, whether originating from historic contamination or current atmospheric deposition, is subject to methylation and a portion is exported as MeHg. With isotopic evidence pointing to the importance of local sources of MeHg to San Francisco Bay foodwebs, we suggest that these conservative flux estimates from a small well-constrained wetland system is consistent with the idea that salt marsh MeHg flux may be a significant source of MeHg to San Francisco Bay.

Wintzer, A., M. Meek, and P.B. Moyle (2010). Life history and population dynamics of Moerisia sp., a non-native hydrozoan in the upper San Francisco Estuary. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

The goal of this study was to investigate the life history and population dynamics of the small, non-native Moerisia sp. in Suisun Marsh, within the upper San Francisco Estuary. Medusae and polyps were collected from 8 and 2 sites, respectively, during 2007 and 2008. Polyps emerged from a resting stage during June,

at a minimum temperature of approximately 14°C. Asexual reproduction of medusae buds was positively correlated with increasing temperature and salinity in summer, while the production of polyp buds was positively related to dissolved oxygen and water transparency levels. Sexual reproduction, defined by the presence of eggs, was related to the size of medusae. Cessation of reproduction of both polyps and medusae occurred in October, when temperatures dropped below 17°C. This life history is similar to other hydrozoans and allows Moersia sp. to reach large numbers seasonally in the San Francisco Estuary, possibly contributing to the recent declines noted of pelagic fish and zooplankton.

Wittmann, M. E., S. Chandra, J.E. Reuter, S.G. Schladow, and B.C. Allen (2010). The Asian clam (Corbicula fluminea) invasion in Lake Tahoe: The ecology and management of an invasive bivalve in an oligotrophic lake. IEP 2010 Annual Workshop. Workshop presentation at the California State University, Sacramento, Sacramento, CA.

Wood, T. M., A. M. Baptista, et al. (1995). "DIAGNOSTIC MODELING OF TRACE-METAL PARTITIONING IN SOUTH SAN-FRANCISCO BAY." Limnology and Oceanography 40(2): 345-358.
The two-dimensional numerical model ELAmet was used to investigate the effect of adsorption kinetics on the apparent distribution coefficients of Cu, Cd, and Zn in south San Francisco Bay, California. The numerical experiments were designed to determine whether adsorption kinetics can control the basin-scale variability of the observed partitioning and to define the conditions under which adsorption kinetics could account for strong interannual variability in partitioning. The numerical results indicate that aqueous speciation will control basin-scale spatial variations in the apparent distribution coefficient, K-d(a), if the system is close to equilibrium. However, basin-scale spatial variations in K-d(a) are determined by the location of the sources of metal and the suspended solids concentration of the receiving water if the system is far from equilibrium. The overall spatial variability in K-d(a) also increases as the system moves away from equilibrium.

Workman, M. L. and J. E. Merz (2007). "Introduced Yellowfin Goby, Acanthogobius flavimanus: diet and habitat use in the Lower Mokelumne River, California." San Francisco Estuary and Watershed Science 5(1).

Wright, S. (2010). Sacramento River sediment sources, transport, and supply to the Delta. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The Sacramento River is the primary source of sediment to the Delta. Recent studies indicate that suspended sediment is an important indicator of habitat quality for endangered native fish. Also, previous work documented decreases in sediment supply from the Sacramento over the past half century in response to anthropogenic impacts. Predictions of future sediment supply in response to climate and water management scenarios require an understanding of sediment sources and transport in the watershed. To this end, this study reviews sediment data collected during 1979 and 1980 when an intensive monitoring program existed in the Sacramento Valley. These data serve to illustrate sources and transport processing during below normal (1979) and above normal (1980) hydrologic conditions. For both years, the primary source of sediment was the upper reaches between Keswick Dam and Hamilton City. In 1979, spills to Sutter and Yolo bypasses were minimal such that the sediment generated in the upper reaches was transported downstream in the main channel to the Delta. Though the Feather River was a significant source of water, its sediment supply was relatively small compared to the supply from the upper reaches (for 1979 and 1980). During 1980, substantial spills occurred to the bypasses and this substantially affected sediment (and water) routing in the system. Sediment loads decreased substantially in the middle reaches as water and sediment were spilled to Sutter bypass. Above Verona, Sutter bypass and the Feather join the Sacramento and can spill into Yolo bypass. In 1980, this resulted in a large increase in downstream Sacramento flows but only a modest increase in sediment loads because of the low sediment load of the Feather as well as deposition in Sutter bypass. Limited data exist for sediment loads in the Yolo bypass and lower Sacramento, and this remains an area for further study.

Wright, S. A. and D. H. Schoellhamer (2004). "Trends in the sediment yield of the Sacramento River, California, 1957 - 2001." San Francisco Estuary and Watershed Science 2(2): Issue 2 Article 2.
Human activities within a watershed, such as agriculture, urbanization, and dam building, may affect the sediment yield from the watershed. Because the equilibrium geomorphic form of an estuary is dependent in part on the sediment supply from the watershed, anthropogenic activities within the watershed have the potential to affect estuary geomorphology. The Sacramento River drains the northern half of California’s Central Valley and is the primary source of sediment to San Francisco Bay. In this paper, it is shown that the delivery of suspended-sediment from the Sacramento River to San Francisco Bay has decreased by about one-half during the period 1957 to 2001. Many factors may be contributing to the trend in sediment yield, including the depletion of erodible sediment from hydraulic mining in the late 1800s, trapping of sediment in reservoirs, riverbank protection, altered land-uses (such as agriculture, grazing, urbanization, and logging), and levees. This finding has implications for planned tidal wetland restoration activities around San Francisco Bay, where an adequate sediment supply will be needed to build subsided areas to elevations typical of tidal wetlands as well as to keep pace with projected sea-level rise. In a broader context, the study underscores the need to address anthropogenic impacts on watershed sediment yield when considering actions such as restoration within downstream depositional areas.

Wright, S. A. and D. H. Schoellhamer (2005). "Estimating sediment budgets at the interface between rivers and estuaries with application to the Sacramento-San Joaquin River Delta." Water Resources Research 41(9).
[1] Where rivers encounter estuaries, a transition zone develops where riverine and tidal processes both affect sediment transport processes. One such transition zone is the Sacramento - San Joaquin River Delta, a large, complex system where several rivers meet to form an estuary (San Francisco Bay). Herein we present the results of a detailed sediment budget for this river/estuary transitional system. The primary regional goal of the study was to measure sediment transport rates and pathways in the delta in support of ecosystem restoration efforts. In addition to achieving this regional goal, the study has produced general methods to collect, edit, and analyze (including error analysis) sediment transport data at the interface of rivers and estuaries. Estimating sediment budgets for these systems is difficult because of the mixed nature of riverine versus tidal transport processes, the different timescales of transport in fluvial and tidal environments, and the sheer complexity and size of systems such as the Sacramento - San Joaquin River Delta. Sediment budgets also require error estimates in order to assess whether differences in inflows and outflows, which could be small compared to overall fluxes, are indeed distinguishable from zero. Over the 4 year period of this study, water years 1999 - 2002, 6.6 +/- 0.9 Mt of sediment entered the delta and 2.2 +/- 0.7 Mt exited, resulting in 4.4 +/- 1.1 Mt (67 +/- 17%) of deposition. The estimated deposition rate corresponding to this mass of sediment compares favorably with measured inorganic sediment accumulation on vegetated wetlands in the delta.

Xu, J., P.M. Glibert, H. Liu, K. Yin, X.Yuan, M. Chen, and P.J. Harrison (2012). "Nitrogen sources and rates of phytoplankton uptake in different regions of Hong Kong Waters in summer." Estuaries and Coasts 35: 13.
Suppression of phytoplankton nitrate uptake by ammonium in a comparative ecosystem is demonstrated

Yee, D., T. Grieb, et al. (2007). "Synthesis of long-term nickel monitoring in San Francisco Bay." Environmental Research 105(1): 20-33.
The Regional Monitoring Program for Water Quality in the San Francisco Bay (RMP) has conducted annual monitoring of the San Francisco Estuary (estuary) since 1993. The RMP primarily monitors water, sediment, and bivalves, although short-term pilot and special studies on select topics are also conducted. The purpose of this article is to synthesize over 10 years of RMP nickel data and to illustrate how comprehensive monitoring data contribute to an understanding of contaminant fate. Nickel concentrations observed in water (43.7-233.7nM) are largely a function of the geology of the watershed surrounding the estuary and inputs from wastewater treatment plants and urban runoff. The geologic formations supplying sediment to the

estuary contain high concentrations of nickel (e.g., 1000-3300 mu g/g). Much of the research to date on nickel speciation suggests that nickel complexes from wastewater treatment plants are not readily available for biological uptake [Bedsworth, W.W., Sedlak, D.L., 1999. Sources and environmental fate of strongly complexed nickel in estuarine waters: the role of ethylenediaminetetraacetate. Environ. Sci. Technol. 33, 926-931, Sedlak, D.L., Phinney, J.T., Bedsworth, W.W., 1997. Strongly complexed Cu and Ni in wastewater effluents and surface runoff. Environ. Sci. Technol. 31(10), 3010-3016, Donat, J.R., Lao, K.A., Bruland, K.W., 1994. Speciation of dissolved copper and nickel in South San Francisco Bay: a multi-method approach. Anal. Chim. Acta. 284, 547-571]. In addition, concentrations of nickel measured in biota by the RMP (0.905-113.0 mu g/g dry weight in bivalve tissues) are well below recommended maximum tissue residue levels (220 mu g/g wet weight, California state guidelines). Based on this information, regulators have reconsidered the water quality objectives developed for nickel.

Yochum, N., R.M. Starr and D.E. Wendt (2011). "Utilizing Fishermen Knowledge and Expertise: Keys to Success for Collaborative Fisheries Research." Fisheries 36(12): 13.

Collaborative fisheries research provides a mechanism for integrating the unique knowledge, experience, and skills of fishermen and scientists. It is a joint intellectual endeavor that begins with the inception of a project and continues until its final stages, with each group having mutual investment in—and ownership of—the project. Collaborative fisheries research promotes communication and trust among fishermen, scientists, and managers and can provide much-needed scientifically valid data for fisheries management. It can enhance federal and state management data collection programs, which span broad sections of coastline, by increasing the ability to detect changes in local metapopulations that may be overfished or underutilized. We describe a methodology for conducting collaborative fisheries surveys and apply it to marine protected areas along the central California coast. During a series of workshops in 2006, attended by members of the fishing, academic, environmental, and management communities, protocols were established for conducting hook-and-line surveys collaboratively with commercial passenger fishing vessel captains and volunteer recreational anglers. The protocols have been implemented annually since 2007. This case study highlights the effectiveness of—and the essential steps in—developing our collaborative fisheries research and monitoring projects.

Yoshiyama, R. M., F.W. Fisher, and P.B. Moyle (1998). "Historical abundance and decline of chinook salmon in the Central Valley region of California." North American Journal of Fisheries Management 18(3): 487-521.

The Central Valley drainage of California formerly produced immense numbers of chinook salmon Oncorhynchus tshawytscha. Four seasonal runs occur in this system—fall, late-fall, winter, and spring runs. Differences in life history timing and spatial distribution enabled the four runs to use the drainage to the fullest possible extent and once made it one of the richest regions in the world for chinook salmon production. Native American fishers within the Central Valley drainage harvested chinook salmon at estimated levels that reached 8.5 million pounds or more annually. Native harvests, therefore, were roughly comparable to the peak commercial harvests taken later by Euro-American fishers, but whether or not native fishing depressed the productive capacities of the salmon populations to any substantial degree is not known. The commercial chinook salmon fishery in California started about 1850 in the San Francisco Bay and Sacramento–San Joaquin Delta region, where it formed the nucleus of the first major fishery conducted by Euro-American immigrants in the state. This fishery was one of the important early industries that supported the Euro-American settlement of the Central Valley region. The salmon fishery remained centered there until the early 1900s, when ocean salmon fishing began to expand and eventually came to dominate the fishery. Annual catches by the early Sacramento–San Joaquin in-river fishery commonly reached 4–10 million pounds and generally were higher than the total statewide catches made during the most recent several decades. The historical abundances of Central Valley chinook salmon before large-scale commercial exploitation and depletion of the runs cannot be determined with certainty. However, on the basis of early commercial catch records, the maximal production levels of the Central Valley chinook salmon stocks in aggregate may be conservatively estimated to have reached approximately 1–2 million spawners annually. Although substantial investment has been made by the state of California in managing the chinook salmon resource since the early years of the commercial fishery, chinook salmon have declined over the decades to small fractions of their previous numbers. The decline of the Central Valley chinook salmon resource was caused by several factors: overfishing, blockage and degradation of streams by mining activities, and reduction of salmon habitat and streamflows by dams and water diversions. Differences between the four chinook salmon runs in life history timing and habitat requirements partly account for their different population histories; the winter run is now threatened with extinction, the spring run recently has approached a similarly imperiled state, and the late-fall run has been at moderately low population levels for the past two decades. Only the fall run, in aggregate, can be regarded as secure, but it too has undergone substantial reductions in abundance. Fall-run spawner numbers were especially low in the San Joaquin River basin in recent years, and in Sacramento River basin streams their numbers have been heavily influenced by production of hatchery fish.

Yoshiyama, R. M. (1999). "A history of salmon and people in the Central Valley region of California." Reviews in Fisheries Science 7: 197-239.
Chinook salmon (Oncorhynchus tshawytscha) formerly occurred in great abundance within the California Central Valley drainage and were a correspondingly important part of the subsistence economics and cultures of the indigenous peoples of that region. Salmon and other fishery resources on the Central Valley floor were part of a resource base that enabled resident Native American groups to attain some of the highest population densities to occur among the non-agricultural native societies of North America. Indirect estimates of aboriginal harvests prior to Euro-American settlement of the region indicate that the native fishers may have exploited the Central Valley salmon resource on a level comparable to that later attained by the immigrant Euro-American fishers of the late ninteenth century commercial fishery. The salmon resource also figured, to varying degrees, in native group interactions-- from trade item to causa belli. Among the last intact native groups in California reliant on a salmon-based subsistence economy were the McCloud River Wintu-- a people who were instrumental in the successful operation of the U.S. Fish Commission egg-collecting station on the lower McCloud River that supplied salmon eggs for shipments to U.S. Eastern states and overseas countries. Prior to 1850, mention of salmon was made perodically by Spanish chroniclers and by European and (U.S.) American observers who traveled through the region.

Yoshiyama, R. M., E.R. Gerstung, F.W. Fisher, and P.B. Moyle (2001). Historical and present distribution of chinook salmon in the Central Valley drainage of California. Contributions to the Biology of Central Valley Salmonids: Fish Bulletin 179. R. L. Brown. Sacramento, CA, State of California, The Resources Agency, Department of Fish and Game. 1: 71-176.
Chinook salmon (Oncorhynchus tshawytscha) formerly were highly abundant and widely distributed in virtually all the major streams of California’s Central Valley drainage—encompassing the Sacramento River basin in the north and San Joaquin River basin in the south. We used information from historical narratives and ethnographic accounts, fishery records and locations of in-stream natural barriers to determine the historical distributional limits and, secondarily, to describe at least qualitatively the abundances of chinook salmon within the major salmon-producing Central Valley watersheds. Individual synopses are given for each of the larger streams that historically supported or currently support salmon runs. In the concluding section, we compare the historical distributional limits of chinook salmon in Central Valley streams with present-day distributions to estimate the reduction of in-stream salmon habitat that has resulted from human activities—namely, primarily the construction of dams and other barriers and dewatering of stream reaches. We estimated that at least 1,057 mi (or 48%) of the stream lengths historically available to salmon have been lost from the original total of 2,183 mi in the Central Valley drainage. We included in these assessments

all lengths of stream that were occupied by salmon, whether for spawning and holding or only as migration corridors. In considering only spawning and holding habitat (in other words, excluding migration corridors in the lower rivers), the proportionate reduction of the historical habitat range was far more than 48% and probably exceeded 72% because most of the former spawning and holding habitat was located in upstream reaches that are now inaccessible for salmon. Individual stream assessments revealed substantial differences among streams in the extent of salmon habitat lost. Some streams experienced little or no reduction (for example, Bear River, Mill Creek) while others were entirely eliminated from salmon production (for example, McCloud, Upper Sacramento, and Upper San Joaquin rivers.)

Yoshiyama, R. M. and F. W. Fisher (2001). "Long Time Past: Baird Station and the McCloud Wintu." Fisheries 26(3): 6-19.
The U.S. Fish Commission's Baird Station, established on the McCloud River at the northern end of the Sacramento Valley in California, was the first salmon hatchery on the North American Pacific Coast. During its early period of operation (1872-1883) under the supervision of fish culturist Livingston Stone, Baird Station produced a reliable and seemingly limitless supply of chinook salmon (Oncorhynchus tshawytscha) eggs for the stocking of eastern U.S. streams and for shipments to overseas countries. The local native people--the McCloud Wintu--played a vital role in the station's operations. Their cultural and economic entwinement with the salmon resource and contribution to the station's mission were recorded in Stone's official reports. That near-forgotten story is retold here for new generations of fisheries workers--of the fish that once were, and of a people who still are.

Yoshiyama, R. M., E. R. Gerstung, et al. (2000). "Chinook Salmon in the California Central Valley: an Assessment." Fisheries 25(2): 6-20.
This paper summarizes information on recent historical distribution and abundance of chinook salmon in the California Central Valley drainage, focusing on the period from the 1950s to today. Most of the principal Central Valley streams that historically supported salmon runs still do so, but nearly half of them have lost at least one seasonal salmon run and several major streams have had all their salmon runs extirpated. Overall abundance of chinook salmon in the Central Valley system has decreased to less than 75% of their number in the 1950s. Fall-run chinook salmon in the Sacramento River basin compose by far the most abundant Central Valley stocks, but they substantially declined between 1953-1966 and 1967-1991. Fall-run chinook salmon stocks in the San Joaquin River basin and Sacramento-San Joaquin Delta tributaries showed various changes between 1953-1966 and 1967-1991 but altogether constitute only a minor portion (now 4%) of the total Central Valley spawning escapements. Three other chinook salmon runs (winter, spring, late-fall) have shown much more pronounced reductions in recent decades. Central Valley salmon have been heavily supported by hatchery production, but the effects of hatcheries on natural stocks remain poorly understood. Major efforts are underway to restore regional chinook salmon and steelhead stocks, several of which are listed under both California and U.S. endangered species statutes.

Young, C. (2010). Development of water evaluation and planning system (WEAP21) weekly hydrologic models for west-slope Sierra Nevada watersheds. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
The impacts of climate change are expected to be particularly acute in mountainous regions such as the Sierra Nevada of California. Increasing temperature and changes in precipitation patterns will result in changes to snow accumulation and melt. These changes will affect a wide range of hydrologic parameters from soil moisture, stream flow, and stream temperature which will in turn affect the natural and human communities that rely on the existing hydrologic regime. Existing hydrologic models of the region do not resolve these changes down to the spatial scale at which many management decisions are made. In response to this, the Center for Watershed Sciences at UC Davis and the Stockholm Environment Institute has developed hydrology models for the western slope of the Sierra Nevada from the Feather to Kern River watersheds. The models were developed to provide hydrologic simulations at a spatial scale useful for assessing the local impacts of climate change on stream flow, stream temperature, and operations management of hydropower

and water supply systems. The models calculate many aspects of the hydrologic cycle including snow accumulation, snow melt, and surface runoff. Weekly predictions of unimpaired stream flows were made at 261 locations throughout the 15 watersheds for the time period 1982-2001. Model input included precipitation and temperature which allowed for analysis of climate change scenarios through the alteration of input weather data. Climate change analysis was conducted through increases in average temperature of 2, 4, and 6 degrees Celsius.

Young, C., L. Fotherby, B. Greimann, J. Richards, M. Tansey, and E. Tozzi (2010). Modeling riparian forest establishment on the Sacramento River. 6th Biennial Bay–Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.

Management of riparian forests along the rivers tributary to the Delta requires the ability to simulate the establishment and survival of riparian vegetation. To address this issue the Stockholm Environment Institute, U.C. Davis, and the U.S. Bureau of Reclamation have developed a suite of modeling tools to study the implications of Sacramento River management operations on riparian forest establishment and survival. The models use as input the flow time series generated by the CALSIM model. This nests the analyses made with these models within the broader context of water management planning in California. The models include representations of channel morphology, sediment transport, point bar development, and riparian forest establishment. At the point bar scale the Riparian Habitat Establishment Model (RHEM) was used to simulate plant growth as a function of atmospheric and soil moisture conditions using a modified version of the variably saturated flow model HYDRUS 2-D. Model algorithms were validated for cottonwood seedlings using controlled field experiments. The outputs from RHEM were then utilized in the SRH-1DV model to study riparian forest establishment on the reach of the Sacramento River between Red Bluff and Colusa. Results from this analysis show that forest establishment is sensitive to river management operations and is more likely on portions of the river with favorable bank geometry and sediment texture. Results from this study will provide river managers valuable information on strategies for increasing riparian forest establishment while minimizing impacts to other management objectives.

Young, D., M. Becerra, et al. (1998). "GC/MS analysis of PCB congeners in blood of the harbor seal. Phoca vitulina from San Francisco Bay." Chemosphere 37(4): 711-733.

Here we report a validated technique for quantifying up to 20 specific PCB congeners in 1-2 g samples of whole blood with a detection limit below 1 ng/g (ppb) wet weight. Specimens were analyzed from 14 harbor seals sampled in south San Francisco Bay, California during 1991-1992. Ratios of specific congeners to PCB-153, and other aspects of congener pattern, agreed with published values for PCB's detected in seal blood. PCB-153 constituted 30 percent of our capital sigma PCB values. The mean capital sigma PCB concentration for the San Francisco Bay seals was 50 ppb, about three times the average level reported for blood of captive seals fed exclusively on fish from the Baltic's PCB-contaminated Dutch Wadden Sea. Such experimental populations have exhibited depressed reproductive success and impaired immune function. These findings support concerns about the ecological effects of PCB contamination in San Francisco Bay.

Young, G., C.L. Brown, R.S. Nishioka, L.C. Folmar, M. Andrews, J.R. Cashman, and H.A. Bern (1994). "Histopathology, blood chemistry, and physiological status of normal and moribund striped bass (Morone saxatilis) involved in summer mortality ('die-off') in the Sacramento-San Joaquin Delta of California." Journal of Fish Biology 44(3): 491-512.

Summer mortality (’die-off‘) is common in striped bass, Morone saxatilis (Walbaum), in the San Francisco Bay-Delta region. Tissue and blood samples of moribund and healthy striped bass collected during the summers of 1986–1988 were analysed. Sixteen moribund and 25 healthy reference fish from the Carquinez Strait area and eight fish caught in the Pacific Ocean were studied. Moribund fish plasma was invariably yellow-orange; most of the moribund fish had discoloured livers with haemorrhagic regions, and approximately one-third had haemorrhagic intestines. Piasma levels of aspartale aminotransferase, uric acid, alkaline phosphatase and cortisol were significantly higher than in reference fish from Carquinez Strait and

the Pacific Ocean, whereas cholesterol, sodium, chloride, triiodothyronine and glucose levels were significantly lower. Hepatic heavy metal concentrations and bacterial content were similar in moribund and reference fish. Gill Na.+, K+ -ATPase activity was significantly lower in moribund fish. Liver, kidney, intestine, and thyroid follicles of moribund fish displayed various histopathological changes, and corticosteroidogenic (interrenal) tissue could not be identified positively in moribund fish. These findings are discussed in relation to recent work on the chemical burdens (industrial and agricultural hydrocarbons) found in livers from some of the fish examined in this study.

Young, M., C. Kendall, S. Silva, R. Dahlgren, P. W. Lehman, and W. Stringfellow (2010). Diel changes in water chemistry and isotopes in the San Joaquin River and Delta: Implications for large-scale monitoring studies. IEP 2010 Annual Workshop. Poster paper presented at the California State University, Sacramento, Sacramento, CA.

Young, M., C. Kendall, W. Stringfellow, S. Silva, and R. Dahlgren (2010). Using a stable isotope mass balance approach to identify nitrate sources and sinks in the San Joaquin River. 6th Biennial Bay-Delta Science Conference. Workshop presentation at the Sacramento Convention Center, Sacramento, California.
Between 2005 and 2007 a large-scale sampling program was conducted in the San Joaquin River (SJR) and tributaries to identify sources and sinks of organic matter and nutrients which contribute to low dissolved oxygen levels in the Stockton Deep Water Ship Channel. The SJR has numerous water inputs and diversions along its length in addition to potential ground water inputs, and while the sampling plan included all of the major tributaries, it was not feasible to sample all of the minor water inputs. In order to provide constraints on nitrate cycling processes such as algal uptake and denitrification, and to identify the presence of significant unmeasured sources or sinks, we performed mass-weighted stable isotope mixing calculations for individual sections of the SJR. Water isotopic composition (d18O and d2H) was used as a conservative tracer, and predicted water isotope values closely matched the measured values throughout most of the study, indicating that all significant water inputs were usually identified by the sampling approach. Nitrate concentrations and isotope mass balances were then calculated for each river section and transect sampling date in order to identify times and locations where nitrate concentrations and/or isotopic compositions did not follow the predicted conservative mixing model, indicating the presence of unidentified nitrate source or sinks. Nitrate isotope values showed more discrepancies than the water isotope values, and the discrepancies between measured and predicted d15N and d18O-NO3 values did not follow the same trends. This suggests that a single in-stream process such as algal uptake or denitrification was not the primary control on downstream nitrate composition. The decoupled discrepancies found for d15N and d18O suggest that unsampled and/or poorly characterized water inputs such as runoff and small drains & tributaries influenced the concentration and isotopic composition of the nitrate in the mainstem SJR, particularly during high flow periods.

Young, P. S., and J. J. Cech Jr (1996). "Environmental tolerances and requirements of splittail." Transactions of the American Fisheries Society 125(5): 664-678.
The range of splittail Pogonichthys macrolepidotus has decreased to less than a third of its original range due to loss or alteration of habitats. We measured the critical thermal minima (CTmin) and maxima (CTmax), critical dissolved oxygen minima (CDOmin), critical salinity maxima (CTmax), salinity endurance, and critical swimming velocity (Ucrit) for age-0 (0.1–4.0 g), age-1 (10–48 g), and immature age-2 (72–201 g) splittails to assist in effective water and habitat management and restoration of this species. Neither thermal acclimation nor fish weight affected the CTmin (6.5–7.3°C), but CTmax (29–33°C) of fish acclimated at 17 and 20°C were higher than CTmax (21–22°C) of fish acclimated at 12°C. Mean CDOmin values were low (0.6–1.3 mg O2/L) for all age-groups, although immature age-2 fish acclimated at 12°C had a lower CDOmin than any group acclimated at 17°C. Mean CTmax (20–29‰) did not vary with acclimation temperature, but increased with increasing weight for fish acclimated at 17°C. Mean time to loss of equilibrium in all age-groups generally decreased as salinity increased and was generally lower for age-0 fish than for those of other age-groups. Mean absolute Ucrit (19.5–66.3 cm/s)

increased with standard length (SL), but relative Ucrit (3.4-6.8 body lengths/s) decreased with SL for fish acclimated at 17°C. Increases in acclimation temperature by 3°C for small age-0 fish and 5°C for age-2 fish increased absolute Ucrit by 11 and 25 em/s, respectively. We conclude that age-0, age-1, and especially age-2 fish are eurythermal, euryhaline, and tolerant of low DO levels and strong water currents. This general hardiness probably permits splittails to exist in harsh estuarine habitats such as dead-end sloughs. A lack of sufficient flooded vegetation for spawning and rearing, narrower environmental tolerances of other life stages (i.e., eggs, larvae, and adult spawners), or biotic factors (e.g., predation, competition) may be limiting splittail abundance and distribution.

Zedler, J. (2005). "Ecological restoration: guidance from theory." San Francisco Estuary and Watershed Science 3(2): [np].
A review of the science and practice of ecosystem restoration led me to identify key ecological theories and concepts that are relevant to planning, implementing, and sustaining restoration efforts. From experience with actual restoration projects, I provide guidance for improving the restoration process. Despite an abundance of theory and guidance, restoration goals are not always achieved, and pathways toward targets are not highly predictable. This is understandable, since each restoration project has many constraints and unique challenges. To improve restoration progress, I advise that sites be designed as experiments to allow learning while doing. At least the larger projects can be restored in phases, each designed as experimental treatments to test alternative restoration approaches. Subsequent phases can then adopt one or more of the treatments that best achieved goals in earlier phases while applying new tests of other restoration measures. Both science and restoration can progress simultaneously. This phased, experimental approach (called "adaptive restoration") is an effective tool for improving restoration when monitoring, assessment, interpretation and research are integrated into the process.

Zeug, S., G. O'Leary, T.R. Sommer, B. Harrell, and F. Feyrer (2002). Introduced palaemonid shrimp invades the Yolo Bypass floodplain. IEP Newsletter. 15: 13-15.

Zeug, S. C., and B.J. Cavallo (2013). "Influence of estuary conditions on the recovery rate of coded-wire-tagged Chinook salmon (Oncorhynchus tshawytscha) in an ocean fishery." Ecology of Freshwater Fish 22(1): 12.
Chinook salmon (Oncorhynchus tschawytscha) populations within the highly modified San Francisco Estuary, California, have seen precipitous declines in recent years. To better understand this decline, a decade of coded-wire tag release and recovery data for juvenile salmon was combined with physicochemical data to construct models that represented alternative hypotheses of estuarine conditions that influence tag recovery rate in the ocean. An information theoretic approach was used to evaluate the weight of evidence for each hypothesis and model averaging was performed to determine the level of support for variables that represented individual hypotheses. A single best model was identified for salmon released into the Sacramento River side of the estuary, whereas two competitive models were selected for salmon released into the San Joaquin River side of the estuary. Model averaging found that recovery rates were greatest for San Joaquin River releases when estuary water temperatures were lower, and salmon were released at larger sizes. Recovery rate of Sacramento releases was greatest during years with better water quality. There was little evidence that large-scale water exports or inflows influenced recovery rates in the ocean during this time period. These results suggest that conceptual models of salmon ecology in estuaries should be quantitatively evaluated prior to implementation of recovery actions to maximise the effectiveness of management and facilitate the recovery of depressed Chinook populations.

Zhang, M., S.L. Ustin, E. Rejmankova, and E.W. Sanderson (1997). "Monitoring Pacific coast salt marshes using remote sensing." Ecological Applications: a publication of the Ecological Society of America 7(3): 1039-1053.
The rapid decline in the extent and health of coastal salt marshes has created a need for nondestructive methods for evaluating the condition of salt marsh ecosystems. This paper describes simultaneous uses of field sampling and remote

sensing approaches to understand salt marsh ecosystem functions and species distributions and discusses the implications for salt marsh monitoring using remote sensing. Three sites along the Petaluma River near the entrance into San Pablo Bay, California, which represented a range of soil salinity, water content, and nutrients, were studied. Standing biomass was directly assessed by field sampling and indirectly estimated through canopy reflectance. The sites were dominated by almost monotypic stands of Salicornia virginica, Spartina foliosa, and Scirpus robustus. For Salicornia, we found a positive relationship between salinity and biomass up to a threshold of 42 g/kg, after which biomass declined monotonically with increasing salinity. No Scirpus or Spartina were found at soil salinities >20 g/kg. Although significantly different levels of nitrate and ammonium nitrogen were found in the interstitial water and soils at these sites, no strong relationships were found between biomass and nitrate nitrogen. Soil ammonium nitrogen, in contrast, was positively related to biomass. Soil redox and salinity increased with elevation and distance from the shoreline, while soil moisture and H_2S decreased. Canopy biomass was estimable using remotely sensed spectral vegetation indices at 58–80% accuracy depending on species. Simple Vegetation Index (VI) and Atmospherically Resistant Vegetation Index (ARVI) measured by handheld field spectrometers were the best estimators of green biomass for high cover of Salicornia. Soil Adjusted Vegetation Index (SAVI) and Soil Adjusted and Atmospherically Resistant Vegetation Index (SARVI) gave the best estimates for Spartina while the Global Environment Monitoring Index (GEMI) was the best estimate for Scirpus. The relationships between vegetation indices and biomass were developed from field spectra. The VI was used to estimate spatial patterns of biomass across the salt marsh from Landsat satellite Thematic Mapper (TM) data. The TM image showed spatial patterns corresponding with species zones and biomass abundance. Narrow band reflectance features measured with a handheld spectrometer can be used to predict canopy plant water content (R^2 = 63%). Interpolated estimates of water content from field-measured canopy reflectance were shown to relate to variation in salinity and soil moisture. Canopy water content was estimated from Airborne Advanced Visible Infrared Imaging Spectrometer data, which showed similar spatial patterns at the site. Results indicate that both biomass production and canopy water content can be accurately determined from remotely sensed spectral measures. Species-specific differences in these characteristics may be used for monitoring species distribution and abundance from airborne or satellite images.

Zimmerman, R. C., J. L. Reguzzoni, et al. (1995). "Eelgrass (Zostera marina L.) transplants in San Francisco Bay: Role of light availability on metabolism, growth and survival." Aquatic Botany 51(1-2): 67-86.

Survival, metabolism and growth of Zostera marina L. transplants were examined along depth gradients in Keil Cove and Paradise Cove in the extremely turbid San Francisco Bay estuary. Water transparency was unusually high throughout 1989-1990 for San Francisco Bay. Transplant survival was strongly depth-dependent at Paradise Cove but not at Keil Cove. All transplants were lost below -1.0 m depth within 1 year at Paradise Cove, but survived to depths of -1.5 m at Keil Cove. Half the transplants growing in shallow water survived the first year at both sites. Shoot photosynthesis, respiration, growth, and sugar content did not differ between sites. Daily periods of irradiance-saturated photosynthesis (H sub(sat)) were over 6 h all year. Seasonal photosynthetic acclimation to light availability maintained long H sub(sat) periods and high ratios of daily whole-plant production to respiration through the winter, indicating a potential for net carbon gain throughout the year. Winter growth was 50% of the summer rate. Despite high initial losses, surviving transplants have persisted at both sites through 1994. Although eelgrass transplants can succeed in San Francisco Bay given sufficient light availability, the role of carbon reserves and transplant timing may influence transplant survival.

Zimmerman, R. C., J. L. Reguzzoni, et al. (1991). "Assessment of environmental suitability for growth of Zostera marina L. (eelgrass) in San Francisco Bay." Aquatic Botany 39: 353-366.

The relationship between turbidity and light availability, and its subsequent effect on the depth distribution of Zostera marina L. (eelgrass) in San Francisco Bay was explored. The average daily period of irradiance-saturated photosynthesis (H sub(sat)) required for the maintenance of whole plant carbon balance and growth, based on measured rates of photosynthesis and respiration as well as data available in the literature, were estimated to be between 3 and 5 h. Estimates of average H sub(sat) availability in the field were determined from laboratory measurements of the phytosynthesis vs. irradiance (P vs. I) response and from field observations of light attenuation measured at five sites in San Francisco Bay. Although plants were found to be low-light adapted with regard to their P vs. I response, they were limited to depths shallower than -2 m mean lower low water (MLLW) at all sites.